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THE PSYCHOLOGICAL REVIEW

ON THE ELIMINATION OF THE TWO EXTREME INTENSITIES OF THE COMPARISON STIMULI IN THE METHOD OF CONSTANT STIMULI

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The investigators who have been interested in the theory of the psychophysical methods, have concerned themselves with two general problems. In the first place, they have sought for a better theoretical understanding of the methods, and of the thresholds and other final values obtained by the use of them. Secondly, they have attempted to standardize each of these methods in such a form, that the time and labor required for obtaining and treating the data would be reduced to a minimum. This second problem has been of special importance for the method of constant stimuli, inasmuch as the time and labor required for experimentation by this method has been, until recently, disproportionately large. But the method of constant stimuli is exceedingly valuable, because we probably have a better theoretical understanding of it than of any other psychophysical method.

Urban attacked the problem of shortening the time required for the calculations involved in the practice of the method of constant stimuli, and in 1912 published certain tables, by the aid of which an investigator may perform the complete calculation of a threshold in less than twenty minutes, once he has obtained the data.[1] It is unlikely that one ever will be able to reduce the calculation to a briefer form than that made

[1] F. M. Urban, 'Hilfstabellen für die Konstanzmethode,' *Arch. fur d. ges. Psychol.*, XXIV., 1912, 236ff.

possible by the use of these tables. Hence it would seem that any further advance towards reducing the labor involved in the practice of this method must consist in altering the experimental technique for the collecting of the data. This may be done in either of two ways; (1) by satisfying oneself with a smaller number of judgments on each comparison pair; and (2) by reducing the number of pairs employed in the determination. In either case, it is of interest to know the effect of such an alteration upon the values of the thresholds.

The question of how many comparison pairs should be employed has not been settled satisfactorily. Of course it would be desirable to use as many as possible; but both the time and the energy of the investigator have their limitations. It seems that the question has been decided chiefly for reasons of convenience; most experimenters employed seven pairs.[1] The differences between the standard stimulus and the largest and the smallest comparison stimulus of the series are as a rule so large that the judgments 'heavier' and 'lighter' respectively have a very high relative frequency. It is a fact that such results have but little influence on the values of h and c, the two quantities which determine the psychometric functions. This suggested the idea of recalculating a series of data, after eliminating the extreme comparison stimuli, and of comparing the results with those obtained in the complete series. The quantities h and c are those employed in the calculation of the thresholds, with which all of the psychophysical methods are primarily concerned; and if the above-mentioned elimination produces little change in the relation of these quantities, the values of the threshold should likewise show but slight variation. That this is actually the case was shown in a recent paper.[2] It was found that the values of the thresholds show very little variation for the averages of a large group of experiments. While individual values for groups of 100 judgments

[1] L. J. Martin and G. E. Müller, 'Zur Analyseder Unterschiedsempfindlichkeit,' Leipzig, 1899, 6ff. F. M. Urban, 'The Application of Statistical Methods to the Problems of Psychophysics,' Philadelphia, 1908, 5ff. S. W. Fernberger, 'On the Relation of the Methods of Just Perceptible Differences and Constant Stimuli,' Psychol. Rev. Monographs, XIV., No. 4, 6ff.

[2] S. W. Fernberger, 'A Simplification of the Practice of the Method of Constant Stimuli,' *Amer. Jour. of Psychol.*, XXV., 1914, 121–130.

on each comparison stimulus show at times rather large and apparently unsystematic variations, still for a large group, these variations tend to cancel one another. An examination of the variations in the measure of sensitivity,—the threshold of Volkmann,—for the extended and for the reduced series reveals a surprising uniformity. Indeed, these values are the more remarkable when we consider that the disregarding of the two extreme comparison stimuli has eliminated one third of the experimental data which forms the basis of the study. The conclusion is that, formally at least, the elimination of the two extreme comparison pairs from the classical form of the method of constant stimuli does not materially affect the values of the thresholds.

There may be a difference between data obtained in a short series and those obtained in a longer series from which the extreme differences were eliminated afterwards. In other words, it may be that the presence of very large differences influences the attitude of the subject. Hence, in order to determine whether the same relations held empirically, we devised the following experiment in the field of lifted weights.[1] In all we employed four subjects; those who kindly consented to act as subjects were Messrs. F. J. O'Brien, D. I. Pope, G. S. Snoddy and R. H. Wheeler, all graduate students in experimental psychology at Clark University. Of this group, two were already trained in our particular technique in lifted weights, as they had both acted as subjects throughout a long series of liftings during the preceding winter and spring. The other two subjects were entirely untrained in this form of experimentation. One of these latter showed great adaptability and his judgments were recorded after less than a ten minute period of practice on the first day. In the case of the other subject, nearly an hour's practice was given him before the hand movements became sufficiently automatic to warrant our recording the judgments.

The stimuli which we presented to the subjects were hollow

[1] The experimental work for this study was performed at Clark University during the autumn of 1913. My thanks are due to the subjects for their faithful and sympathetic coöperation, and also to Professor J. W. Baird, Professor F. M. Urban and Dr. S. C. Fisher for their many helpful suggestions.

brass cylinders, 2.5 inches in diameter and 1 inch high, which were closed at one end. In none of their dimensions did they show a variation greater than 0.001 inch. A different number had been stamped on each cylinder, with a small steel die, so that the experimenter could differentiate between the different stimuli. Thus our stimuli were of the same shape as those which have been employed in earlier investigations. They differ from previously employed stimuli, however, in the manner of weighting.[1] The latter have been loaded to the proper intensity with shot and paraffine, the paraffine being inserted in order to hold the shot stationary. But the paraffine is not entirely anhydroscopic and for this reason the stimuli vary in weight. Experimenters have usually corrected any stimulus which showed a variation of more than ten milligram from its proper intensity. Our cylinders, which were weighted with solder, were entirely anhydroscopic. They have been under observation and in use for about a year and none of them ever showed a greater variation than six milligrams.

We prepared a series of stimuli of the following intensities: (*a*) fourteen weights of 100 grams each, of which twelve served as the standard stimuli for each pair; (*b*) two weights each of the following intensities: 88, 92, 96, 104 grams; (*c*) single weights of 84 and 108 grams. We arranged this group of weights into two complete series; one, a classical extended series of seven comparison pairs in which the comparison stimuli weighed 84, 88, 92, 96, 100, 104 and 108 grams; and the other, a reduced series with 88, 92, 96, 100 and 104 gram comparison stimuli. The second series was exactly similar to the first except that in it the two extreme intensities of the comparison stimuli were eliminated. Each of these comparison stimuli was compared with a standard stimulus of 100 grams. We shall use the expression '*extended series*' to designate the complete series of seven pairs of comparison weights; and we shall refer to the second series of five pairs as the '*reduced series*.'

The manner of lifting was the same as that employed in our

[1] F. M. Urban, *ibid.*, 1ff. S. W. Fernberger, *ibid.*, 7ff.

former study.[1] The weights were arranged about the circumference of a circular table with a revolving top. By means of this arrangement each weight could be brought in successive fashion directly under the hand of the subject, and in this way the space error was eliminated. The time error was present in the first order; that is, the standard weight was always lifted first and the comparison weight second. This error was kept constant by controlling the motions of the hand by the beats of a metronome. The metronome was set at 92 beats per minute and the lifting of each stimulus covered a period of four beats.[2]

The disposal of our weights was as follows. Numbers from one to twenty-four were printed about the circumference of the table. The standard stimuli were placed on the odd, and the comparison stimuli on the even numbers of the table. Hence by a complete revolution of the table, we secured a judgment on each of the comparison pairs for both the reduced and extended series. The comparison stimuli were not arranged about the table in a haphazard manner; but their order was carefully planned so that (1) the subject would acquire as little knowledge as possible regarding the objective relation of the stimuli; and (2) so that the effects of the order of presentation would be minimized.

TABLE I

Table Numbers	First Arrangement	Second Arrangement
1 and 2	92	104
3 and 4	100	92
5 and 6	88	84
7 and 8	108	100
9 and 10	96	108
11 and 12	104	88
13 and 14	84	96
15 and 16	92	104
17 and 18	100	92
19 and 20	88	100
21 and 22	96	88
23 and 24	104	96

[1] S. W. Fernberger, 'On the Relation of the Methods of Just Perceptible Differences and Constant Stimuli,' PSYCHOL. REV. Monographs, XIV., No. 4, 1913, 7–18.

[2] Cf. S. W. Fernberger, *ibid.*, 10f.

Two arrangements of the stimuli were used in the experiment, which are given in Table I. The first column contains the numbers on the stimulus table in pairs; the second and third columns contain the intensities of the comparison stimuli. The arrangement was changed after 200 judgments had been secured on each comparison pair. The subjects were not informed that the change was to be made; all subjects later reported not to have been aware of any alteration, which indicates that they had neither acquired any knowledge of the objective relations of the stimuli nor learned the order of their succession. Three complete series of judgments were usually secured from one subject, upon which he was allowed to rest for a brief period. This minimized the effect of fatigue. When experimentation was resumed, after the rest, the first two judgments were not recorded, this period being allowed for the hand movements of the subject to become more regular. The intensity of the weights which were lifted at the start of a series was varied. Furthermore, in order that the subject should have no knowledge of the objective relations of the stimuli which were being presented to him, the table was entirely screened from view; the hand of the subject passing through an aperture in this screen.

Immediately after the lifting of the comparison stimulus of each pair, the subjects gave a judgment in terms of the three categories lighter, equal and heavier. A lighter or heavier judgment indicated that the second weight of the pair was subjectively lighter or heavier than the first weight. The equality judgment included not only all cases of actual subjective equality between the stimuli, but also all cases in which the subject was unable to formulate a judgment of heavier or lighter,—the so-called doubtful cases.

With the arrangement of stimuli and the manner of procedure which we have described above,[1] we obtained from

[1] In the description of our experimental arrangement we have spoken as if 24 stimuli had been employed: 12 standard stimuli, 7 comparison stimuli for the extended series, and 5 for the reduced series. We did this for the sake of clearness of exposition, and of differentiating more sharply between the extended and the reduced series. In reality, however, we employed only 14 stimuli, a complete series of 7 pairs for the extended series of the classical form. For the extended series, we obtained a judgment

each subject 500 judgments on each of the comparison pairs for both the extended and the reduced series, making a total of 24,000 individual judgments. We believe that these data are sufficient in quantity to make our results conclusive. By this experimental arrangement, moreover, the experiments for the extended and the reduced series were mingled and performed at the same time, so that we may assume that they were made under similar conditions. The subjects were not informed as to the nature of the problem, or as to the intensities of the stimuli; and their reports indicated that they possessed no knowledge of the objective relations. Finally, by our choice of trained and untrained subjects, we believe that we shall be able to ascertain the relations of the thresholds both for the extended and the reduced series, for two distinct stages of progressive practice.

After completing our calculations we found that the results from one of our subjects were of such a nature that they must be treated separately; but nevertheless they were quite in accord with the results which we obtained from the other three subjects, so far as our main problem is concerned. We shall treat the results of this subject *in extenso* at the end of this paper.

Tables II., III. and IV. contain the observed relative frequencies of Subjects I., II. and III. respectively, both for the extended and the reduced series. These three tables show a similar arrangement. The 500 judgments obtained from each subject have been divided into five groups of 100 judgments each, in the order in which they were taken. The Roman

for each of the pairs; the top of the table was revolved so that the stimuli were presented to the subject in successive fashion. For the reduced series, the cylinders of the five central intensities of the comparison stimulus were presented in the same manner to the subject. When we came to one of the extreme intensities of the comparison stimulus, which we wished to eliminate, the table was swung through a larger arc so that the two weights—the standard and comparison stimuli of the eliminated pair—passed under the hand of the subject, and the standard stimulus of the next pair was actually presented to him. Seldom did the subjects report that they were aware of the table having been moved through a larger arc than usual. But the possession of this knowledge would not have aided our subjects, for the reason that they were ignorant of the problem and of the objective relation of the stimuli. By the use of 14 instead of 24 weights, our experimental technique was very much simplified, while apparently the validity of our method was not affected.

Table II

Groups	Extended Series																				
	84			88			92			96			100			104			108		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.
I.	0.97	0.02	0.01	0.94	0.02	0.04	0.73	0.09	0.18	0.65	0.12	0.23	0.22	0.06	0.72	0.18	0.06	0.76	0.06	0.03	0.91
II.	0.98	0.02	0.00	0.94	0.00	0.06	0.83	0.03	0.14	0.54	0.06	0.40	0.26	0.06	0.68	0.13	0.06	0.81	0.02	0.02	0.96
III.	0.93	0.06	0.01	0.96	0.03	0.01	0.87	0.06	0.07	0.41	0.31	0.28	0.30	0.17	0.53	0.10	0.09	0.81	0.03	0.07	0.90
IV.	0.97	0.03	0.00	0.94	0.05	0.01	0.81	0.14	0.05	0.36	0.33	0.31	0.21	0.23	0.56	0.11	0.16	0.73	0.08	0.08	0.84
V.	0.94	0.01	0.05	0.93	0.05	0.02	0.69	0.16	0.15	0.46	0.16	0.38	0.19	0.17	0.64	0.13	0.07	0.80	0.07	0.03	0.90

Groups	Reduced Series														
	88			92			96			100			104		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.
I.	0.94	0.03	0.03	0.58	0.15	0.26	0.53	0.08	0.39	0.36	0.13	0.51	0.10	0.05	0.85
II.	0.94	0.05	0.01	0.69	0.08	0.23	0.47	0.08	0.45	0.32	0.08	0.60	0.12	0.09	0.79
III.	0.97	0.03	0.00	0.84	0.12	0.04	0.38	0.27	0.35	0.25	0.24	0.51	0.15	0.13	0.72
IV.	0.87	0.10	0.03	0.81	0.14	0.05	0.36	0.28	0.36	0.29	0.22	0.49	0.10	0.23	0.67
V.	0.87	0.09	0.04	0.75	0.13	0.12	0.30	0.19	0.51	0.24	0.15	0.61	0.11	0.12	0.77

Table III

Groups	Extended Series																				
	84			88			92			96			100			104			108		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.
I.	0.70	0.12	0.18	0.63	0.18	0.19	0.45	0.22	0.33	0.33	0.28	0.39	0.14	0.21	0.65	0.10	0.17	0.73	0.04	0.05	0.91
II.	0.71	0.14	0.15	0.70	0.15	0.15	0.51	0.28	0.21	0.36	0.29	0.35	0.10	0.40	0.50	0.05	0.29	0.66	0.02	0.11	0.87
III.	0.56	0.40	0.04	0.51	0.47	0.02	0.21	0.66	0.13	0.05	0.53	0.42	0.03	0.32	0.65	0.00	0.25	0.75	0.00	0.12	0.88
IV.	0.46	0.53	0.01	0.50	0.47	0.03	0.21	0.66	0.13	0.08	0.47	0.45	0.01	0.38	0.61	0.00	0.17	0.83	0.00	0.09	0.91
V.	0.52	0.44	0.04	0.46	0.45	0.09	0.15	0.65	0.20	0.04	0.36	0.60	0.01	0.15	0.84	0.00	0.13	0.87	0.00	0.03	0.97

Groups	Reduced Series														
	88			92			96			100			104		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.
I.	0.60	0.20	0.20	0.34	0.34	0.32	0.24	0.25	0.51	0.09	0.11	0.80	0.09	0.12	0.79
II.	0.69	0.23	0.08	0.32	0.41	0.27	0.18	0.39	0.43	0.06	0.36	0.58	0.03	0.29	0.68
III.	0.52	0.46	0.02	0.25	0.61	0.14	0.07	0.52	0.41	0.02	0.42	0.56	0.02	0.19	0.79
IV.	0.53	0.45	0.02	0.19	0.65	0.16	0.03	0.57	0.40	0.04	0.44	0.52	0.00	0.26	0.74
V.	0.52	0.43	0.05	0.15	0.58	0.27	0.05	0.40	0.55	0.02	0.27	0.71	0.01	0.11	0.88

Table IV

Groups.	Extended Series																				
	84			88			92			96			100			104			108		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h	l.	e.	h.
I.	0.98	0.02	0.00	0.95	0.01	0.04	0.82	0.05	0.13	0.70	0.15	0.15	0.17	0.12	0.71	0.13	0.06	0.81	0.06	0.03	0.91
II.	0.99	0.00	0.01	0.97	0.02	0.01	0.88	0.03	0.09	0.72	0.04	0.24	0.23	0.12	0.65	0.22	0.06	0.72	0.03	0.00	0.97
III.	0.98	0.02	0.00	0.93	0.06	0.01	0.81	0.16	0.03	0.41	0.37	0.22	0.12	0.32	0.56	0.08	0.20	0.72	0.04	0.08	0.88
IV.	0.98	0.02	0.00	0.98	0.02	0.00	0.78	0.20	0.02	0.48	0.43	0.09	0.09	0.56	0.35	0.09	0.23	0.68	0.03	0.09	0.88
V.	1.00	0.00	0.00	1.00	0.00	0.00	0.89	0.08	0.03	0.67	0.23	0.10	0.08	0.51	0.41	0.04	0.21	0.75	0.00	0.02	0.98

Groups.	Reduced Series														
	88			92			96			100			104		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.
I.	0.91	0.02	0.07	0.55	0.15	0.30	0.37	0.21	0.42	0.11	0.11	0.78	0.13	0.04	0.83
II.	0.90	0.04	0.06	0.55	0.14	0.31	0.34	0.11	0.55	0.30	0.06	0.64	0.14	0.09	0.77
III.	0.92	0.06	0.02	0.80	0.13	0.07	0.43	0.29	0.28	0.16	0.31	0.53	0.07	0.19	0.74
IV.	0.92	0.07	0.01	0.75	0.22	0.03	0.44	0.31	0.25	0.09	0.52	0.39	0.05	0.32	0.61
V.	0.90	0.08	0.02	0.81	0.16	0.03	0.52	0.30	0.18	0.16	0.39	0.45	0.04	0.19	0.77

numerals in the first columns indicate these groups. Three columns are given to each comparison weight, in which appear the frequencies of the lighter, equal and heavier judgments on that weight. Reading from left to right, the first seven groups of three columns give the observed relative frequencies for the different comparison stimuli of the extended series in the order of their intensity. The last five groups of three columns show a similar arrangement for the reduced series.

From these data, we have calculated three groups of thresholds for the directions both of increase and decrease. First, the thresholds for the extended series of seven pairs of comparison stimuli have been calculated. Second, formal values of the reduced series from the data of the extended series have been calculated, by disregarding the two extreme intensities of the comparison stimuli. Third, the thresholds from the observed relative frequencies of the reduced series of five pairs of stimuli have been calculated. We shall refer to these three types of values as the threshold values of the *extended series*, of the *reduced series calculated* and of the *reduced series observed* respectively. These thresholds were all calculated in the usual manner by an application of the method of least squares and the use of Urban's tables, noted above. By this method the investigator obtains two values—h and c—from the frequencies both of the heavier and lighter judgments for every series. These quantities determine the form and position of the curves of the psychometric functions for all three categories of judgment. Moreover the relation between them of c/h defines the value of the threshold. The threshold in the direction of increase is obtained from the frequencies of the heavier judgments. The threshold in the direction of decrease is obtained, when we employ the relative frequencies of the lighter judgments. In our present study, both thresholds were calculated for every group of 100 judgments in the extended and reduced series, both calculated and observed, for all four subjects. Thus it was necessary to calculate in all 120 thresholds. Several years ago the labor of such a task would have been entirely disproportionate to

the result obtained, but with the use of Urban's tables neither the labor nor the time involved were excessive.[1]

Table V

Groups	S_1			S_2		
	Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed
I.	97.07	97.03	96.00	98.78	98.59	98.06
II.	96.81	96.90	96.19	97.80	97.86	97.85
III.	96.22	96.65	96.49	99.65	99.43	99.85
IV.	96.33	95.80	95.70	100.00	99.73	100.27
V.	95.68	95.62	93.87	98.25	98.28	98.11

Table VI

Groups	S_1			S_2		
	Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed
I.	90.50	91.76	89.29	96.53	97.27	95.42
II.	91.16	92.20	90.20	98.99	99.91	98.58
III.	86.30	87.80	87.82	98.53	98.44	98.63
IV.	85.23	87.91	87.79	98.24	98.01	99.13
V.	85.50	87.28	87.41	95.62	95.66	96.21

Table VII

Groups	S_1			S_2		
	Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed
I.	94.66	94.83	94.12	98.55	98.30	96.50
II.	98.24	98.35	94.66	99.31	99.52	96.86
III.	95.64	95.46	95.52	100.46	100.18	99.86
IV.	96.01	95.97	96.46	102.01	101.85	101.77
V.	96.76	96.76	95.64	100.90	101.08	100.50

Tables V.–VII. contain the values of the thresholds for subjects I., II. and III. respectively. Each table gives these values for each of the three forms of calculation for every group

[1] For a detailed description of this form of calculation *cf.*: S. W. Fernberger, 'On the Relation of the Methods of Just Perceptible Differences and Constant Stimuli,' Psychol. Rev. Monographs., XIV., No. 4, 1913, 29–38. F. M. Urban, 'Hilfstabellen für der Konstanzmethode,' *Arch. f. d. ges. Psychol.*, XXIV., 1912, 236ff. S. W. Fernberger, 'A Simplification of the Practice of the Method of Constant Stimuli,' *Amer. Jour. of Psychol.*, XXV., 1914, 124ff.

of 100 judgments. As before, the Roman numerals of the first columns refer to the subgroups of 100 judgments. In the next three columns are found the values assumed by the threshold in the direction of decrease (S_1); the first of these refers to the extended series, the second to the reduced series calculated, and the third column to the reduced series observed. The next three columns show a similar arrangement for the values assumed by the threshold in the direction of increase (S_2).

For any one subject, these values of the thresholds are very similar on the whole, but they are by no means identical. The individual values show certain unsystematic variations, such as are generally found in a series of this sort. No regular tendencies seem to be present for the thresholds in any one set, derived from any one of the three sources. A closer scrutiny of the three thresholds for the extended and the reduced series for any one of the subjects reveals an interesting similarity among the results. Whenever a subgroup shows a variation in either direction from the preceding subgroup for the extended series, a variation in the same direction occurs for the reduced series, both calculated and observed, in corresponding subgroups. This relation does not hold absolutely for all our subjects; still in the case of subject III. (Table VII.), it holds with but a single exception (Series V, S_1, reduced series observed).

The relations between the series become more apparent when we consider the quantities which are obtained directly from the values of the thresholds. The interval of uncertainty is defined as the distance between the two thresholds ($S_2 - S_1$). The threshold of Volkmann (which is recognized as the measure of sensitivity), is one half of this value [$(S_2 - S_1)/2$]. The point of subjective equality is defined as the average or mean of the two thresholds [$(S_2 + S_1)/2$]. These three values depend upon the thresholds and are easily obtained when once the thresholds are calculated. Now a psychophysical method is essentially a prescription for the collection of data and for their evaluation, so that the result enables one to compare the sensitivity of two subjects, or that of the same subject at dif-

ferent times or under different conditions. Hence the measure of sensitivity and the point of subjective equality are the final goals of these methods; the first gives the measure of sensitivity, while the second enables one to ascertain the extent of the effect of the constant errors. Hence these quantities may be used as a basis for discussing the variations under consideration.

TABLE VIII

Groups	Interval of Uncertainty			Measure of Sensitivity			Point of Subjective Equality		
	Extended Series	Reduced Series		Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed		Calculated	Observed
I.	1.71	1.56	2.06	0.85	0.78	1.03	97.92	97.81	97.03
II.	0.99	0.96	1.66	0.50	0.48	0.83	97.30	97.38	97.02
III.	3.43	2.78	3.36	1.72	1.39	1.68	97.94	98.04	98.17
IV.	3.67	3.93	4.57	1.84	1.96	2.28	98.16	97.76	97.99
V.	2.57	2.66	4.24	1.28	1.33	2.12	96.96	96.95	95.99
Average...	2.47	2.38	3.18	1.24	1.19	1.59	97.66	97.59	97.24

TABLE IX

Groups	Interval of Uncertainty			Measure of Sensitivity			Point of Subjective Equality		
	Extended Series	Reduced Series		Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed		Calculated	Observed
I.	6.03	5.51	6.13	3.02	2.76	3.06	93.52	94.52	92.36
II.	7.83	7.71	8.38	3.92	3.86	4.19	95.08	96.06	94.39
III.	12.23	10.64	10.81	6.12	5.32	5.40	92.42	93.12	93.22
IV.	13.01	10.10	11.34	6.50	5.05	5.67	91.74	92.96	93.46
V.	10.12	8.38	8.80	5.06	4.19	4.40	90.56	91.47	91.81
Average...	9.84	8.47	9.09	4.92	4.24	4.54	92.66	93.63	93.05

TABLE X

Groups	Interval of Uncertainty			Measure of Sensitivity			Point of Subjective Equality		
	Extended Series	Reduced Series		Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed		Calculated	Observed
I.	3.89	3.47	2.38	1.94	1.74	1.19	96.60	96.56	95.31
II.	1.07	1.17	2.20	0.54	0.58	1.10	98.78	98.94	95.76
III.	4.82	4.72	4.34	2.41	2.36	2.17	98.05	97.82	97.69
IV.	6.00	5.88	5.31	3.00	2.94	2.66	99.01	98.91	99.12
V.	4.14	4.32	4.86	2.07	2.16	2.43	98.83	98.92	98.07
Average...	3.98	3.91	3.82	1.99	1.96	1.91	98.25	98.23	97.19

Tables VIII.–X. show the values of these three quantities for subjects I., II. and III. respectively. As previously, the first columns indicate the subgroups of 100 judgments each. The next three columns give the values assumed by the interval of uncertainty for all three modes of procedure. In the first of these appear the values for the extended series. The next column contains these same values for the reduced series calculated. The third column contains the same values obtained for the reduced series observed. The next three columns contain a similar arrangement for the measure of sensitivity; and the last three, for the point of subjective equality. The bottom row of each table contains the averages of the numbers in the various columns.

Let us first compare the values obtained for the extended series with those obtained for the reduced series calculated. The results which are yielded by this comparison are very similar to the results of our former calculation.[1] If one then compare the measure of sensitivity for the different subgroups, one finds relatively great, and by no means regular, variations. The averages for subjects I. and III. are very similar indeed; the differences between the measures of sensitivity as obtained from the extended series, and those obtained from the reduced series calculated are respectively − 0.05 and − 0.03 grams. In the case of subject II., this difference is considerably greater, being − 0.68 grams. It will be noted, however, that the measure of sensitivity of this subject is relatively very large.

When the values assumed by the measure of sensitivity for the extended series and those for the reduced series observed are compared, one finds a similar state of affairs. The values for the subgroups show greater variations here than they did when the values of the extended series and of the reduced series calculated were compared. For subject I., a comparison of the averages for the extended and for the reduced series observed reveals the fact that the variation is larger; the difference being + 0.35 grams. For subject II., the difference between the values for the reduced series observed and that

[1] S. W. Fernberger, 'A Simplification of the Practice of the Method of Constant Stimuli,' *Amer. Jour. of Psychol.*, XXV., 1914, 125ff.

for the extended series is smaller than the calculated value in the same comparison; the difference being − 0.38. We find for subject III. again a very close approximation; the value of the measure of sensitivity for the reduced series observed being only 0.08 grams less than that for the extended series. It might be of interest to note here that subjects I. and II. were our untrained observers, while Subject III. possessed a rather high degree of training in the technique of this experiment.

When the magnitudes of the point of subjective equality for the reduced series, both calculated and observed, are compared with those for the extended series, unsystematic variations such as we should expect are again found. A closer analysis shows that there existed in addition certain systematic variations; these will appear more clearly when we consider the averages for each subject. In the case of subjects I. and III., the points of subjective equality for the reduced series, both calculated and observed, are smaller than those for the extended series. In both cases the values of the reduced series observed show greater variation from those of the extended series than do the values of the reduced series calculated. In the case of subject II., the values of both of the reduced series are larger than the value for the extended series.

It is doubtful whether the method of constant stimuli may ever be employed properly for anything except an extended study in which more or less highly trained subjects are employed. The effect of progressive practice would seem to preclude the use of this method for short series; and this effect would also prevent the application of the method for anthropometric purposes. In an extended study, it is proper that a large number of judgments be obtained from several subjects. After the results for each subject have been treated separately, it is proper that the combined results for all subjects be considered; with the exception of those which must be eliminated because of abnormal variations. For example *cf.* the case of subject IV. whose results are to be treated separately. Table XI. contains the averages of these three final values for our subjects I., II. and III. The columns give, in order, the values

obtained for the extended series, for the reduced series calculated, and for the reduced series observed, in the order mentioned. The first line contains the values for the interval of uncertainty, and the second and third lines contain respectively the values of the measure of sensitivity and of the point of subjective equality.

TABLE XI

	Extended Series	Reduced Series	
		Calculated	Observed
Interval of uncertainty	5.43	4.92	5.36
Measure of sensitivity	2.72	2.46	2.68
Point of subjective equality	96.16	96.48	95.82

Our results reveal the fact that the value of the measure of sensitivity for the extended series is slightly larger than the values for the reduced series, calculated and observed. The difference between the value of the measure of sensitivity for the extended series and that for the reduced series calculated is − 0.26 grams; while the difference between the value of the measure of sensitivity for the extended series and that for the reduced series observed is only − 0.04 grams. The difference between the measure of sensitivity for the extended series and the reduced series observed may be disregarded as we might expect a difference of at least 0.26 grams, since such is the difference between the values of the extended series and the reduced series calculated. It is, of course, a mere matter of chance that the value of the reduced series observed should more nearly approximate the value for the extended series than does that for the reduced series calculated. The difference between the value of the extended series and that of the reduced series calculated is slightly larger than the corresponding difference obtained in our former study.[1] But in the present case, these variations are so small that they may be entirely disregarded in an extended study.

When we consider the averages of the points of subjective equality for our three subjects, we find that the value for the reduced series calculated is greater than that for the extended

[1] S. W. Fernberger, 'A Simplification of the Practice of the Method of Constant Stimuli,' *Amer. Jour. of Psychol.*, XXV., 1914, 128.

series, the difference being + 0.32 grams. This signifies that the higher values for subject II. more than cancelled the smaller values found for subjects I. and III. When we compare the value of the reduced series observed with that of the extended series, we find that the former is somewhat smaller; the difference being − 0.34 grams. Again we believe that variations so minute as these may be entirely disregarded.

From the above findings we conclude that an investigator using the method of constant stimuli is justified in using a less extended series of comparison stimuli than the classical series of seven pairs. For we have shown that the elimination of the two extreme intensities of the comparison stimuli does not produce any considerable effect upon the values either of the measure of sensitivity or of the point of subjective equality, when we employ a long series of experiments. Such variations as may occur seem to be of a chance character and they tend to cancel one another. Moreover, these variations are so small that they may be entirely disregarded. In our former study, we showed that the above conclusions hold from formal considerations alone; our present study indicates that the same conclusions hold upon the basis of an extended body of experimental data. The elimination of the two extreme intensities obviously reduces the time and labor required for the accumulation of the data by nearly one third. This reduction becomes all the more important when we consider that the method of constant stimuli can be employed only in an extended series of experiments.

We shall now turn to a consideration of the data which we obtained from subject IV. This subject possessed at the outset the same amount of training as subject III. A study of his reactions in the former experiment[1] reveals the fact that he did not show the variations from the normal which appeared in his reactions in the present study. Table XII. contains the observed relative ferquencies of the different judgments for this subject; Table XIII. contains his values of the thresholds;

[1] The results of this study have not yet been published. The experiments were performed during the winter and spring of 1913, and in them an attempt was made to secure an introspective analysis of the comparison consciousness involved in the judgment of small differences in lifted weights.

Table XII

Groups	Extended Series																				
	84			88			92			96			100			104			108		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	'e.	h.
I.	0.97	0.00	0.03	0.89	0.01	0.11	0.77	0.01	0.22	0.56	0.02	0.42	0.27	0.01	0.72	0.13	0.02	0.85	0.04	0.00	0.96
II.	0.98	0.00	0.02	0.92	0.00	0.08	0.72	0.00	0.28	0.68	0.00	0.32	0.38	0.00	0.62	0.23	0.00	0.77	0.09	0.00	0.91
III.	0.77	0.06	0.17	0.76	0.02	0.22	0.56	0.13	0.31	0.57	0.08	0.35	0.29	0.12	0.59	0.18	0.08	0.74	0.18	0.07	0.75
IV.	0.68	0.00	0.32	0.87	0.01	0.12	0.68	0.05	0.27	0.41	0.01	0.58	0.35	0.05	0.60	0.30	0.07	0.63	0.30	0.01	0.69
V.	0.76	0.06	0.18	0.84	0.04	0.12	0.64	0.05	0.31	0.42	0.07	0.51	0.38	0.01	0.61	0.20	0.02	0.78	0.23	0.06	0.71

Groups	Reduced Series														
	88			92			96			100			108		
	l.	e.	h.	l.	e.	h.	l.	e.	h.	l.	e.	h.	.	e.	h.
I.	0.86	0.00	0.14	0.58	0.01	0.41	0.39	0.00	0.61	0.34	0.00	0.66	0.22	0.00	0.78
II.	0.92	0.00	0.08	0.57	0.00	0.43	0.42	0.00	0.58	0.23	0.00	0.77	0.18	0.00	0.82
III.	0.78	0.04	0.18	0.65	0.07	0.28	0.42	0.12	0.46	0.30	0.05	0.65	0.25	0.02	0.73
IV.	0.78	0.02	0.20	0.73	0.00	0.27	0.33	0.08	0.59	0.33	0.02	0.65	0.29	0.02	0.69
V.	0.73	0.04	0.23	0.67	0.05	0.28	0.43	0.06	0.51	0.29	0.06	0.65	0.20	0.06	0.74

and Table XIV. contains the values assumed in his case by the interval of uncertainty, by the measure of sensitivity and by the point of subjective equality for all three of our classes of comparison. These tables are arranged in the same fashion as were the corresponding ones which we have discussed above. For the first two subgroups of 100 judgments each, our objective conditions were precisely the same as those for the other observers. In his first subgroup of 100 reactions, Subject IV.

TABLE XIII

Groups	S_1			S_2		
	Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed
I.	96.52	96.53	95.40	96.77	96.82	95.47
II.	98.12	98.14	95.11	98.12	98.14	95.11
III.	94.96	95.15	95.43	98.06	97.81	97.18
IV.	96.41	96.70	95.82	97.79	97.92	96.66
V.	95.80	95.91	94.93	97.53	96.92	96.55

TABLE XIV

Groups	Interval of Uncertainty			Measure of Sensitivity			Point of Subjective Equality		
	Extended Series	Reduced Series		Extended Series	Reduced Series		Extended Series	Reduced Series	
		Calculated	Observed		Calculated	Observed		Calculated	Observed
I.	0.30	0.24	0.07	0.15	0.12	0.04	96.67	96.65	95.44
II.	0.00	0.00	0.00	0.00	0.00	0.00	98.12	98.14	95.11
III.	3.10	2.66	1.75	1.55	1.33	0.88	96.56	96.48	96.30
IV.	1.38	1.22	0.84	0.69	0.61	0.42	97.10	97.31	96.24
V.	1.73	1.01	1.62	0.86	0.50	0.81	96.66	96.42	95.74
Average III., IV., VI.	2.07	1.63	1.40	1.03	0.81	0.70	96.77	96.74	96.09

gave an exceedingly small number of equality judgments. The interval of uncertainty is directly dependent upon the relative number of equality judgments, and in his first 100 judgments his values for the extended series, for the reduced series calculated and for the reduced series observed were respectively 0.30, 0.24 and 0.07 grams. In spite of these abnormal results we continued with the same objective experimental arrangement and we endeavored by means of non-suggestive questioning to ascertain the factor or factors which were responsible

for the abnormalities. The results of this questioning will be given later.

In the second subgroup of 100 experiments, we obtained the even more remarkable finding that not a single equality judgment was given during the whole 1,200 judgments which were obtained in our extended and reduced series. In this case the thresholds in the directions of increase and decrease coincide, and hence we obtain the result that the interval of uncertainty is zero, as is also the measure of sensitivity. This means that if we compare, with our standard stimulus, any varying comparison stimulus whatsoever, the latter would be judged heavier or lighter with a probability of 0.5 or over. And furthermore, this holds even though the variation be infinitely small. Such a state of affairs is obviously impossible from either theoretical or experimental considerations.

Accordingly after the first two subgroups of 200 judgments had been completed, we altered one factor in our objective experimental arrangement by reducing the interval between our different comparison stimuli from 4 to 2 grams. Hence for the last 300 judgments—the last three subgroups in the tables—Subject IV. was given an extended series of seven comparison stimuli whose intensities were 92, 94, 96, 98, 100, 102 and 104 grams; and he was given a reduced series of five stimuli whose intensities were 94, 96, 98, 100 and 102 grams. Our object in employing such a series of comparison weights was to obtain a greater frequency of equality judgments if this could be secured by means of the introduction of a greater number of stimuli within the limits of the normal interval of uncertainty. In this object we were successful in a certain measure, as appears from the size of the intervals of uncertainty for the last three subgroups of 100 judgments each. Nevertheless, when the reduced interval was employed, the values which were obtained for the measure of sensitivity were considerably smaller than the normal values obtained with the use of a four gram interval between the comparison stimuli. Furthermore, it will be observed that the relative frequencies for the different categories of judgments on the various comparison weights do not by any means conform to

the usual type of curves of the psychometric functions.[1] This is particularly true as regards the curve of the equality judgments. These then are our reasons for disregarding the data which we obtained from subject IV. in our consideration of the primary problem of this study, namely, the effect of the elimination of the two extreme intensities of the comparison stimuli from the classical series of the method of constant stimuli.

We believe that the explanation of the abnormal character of the results which we obtained from subject IV., is to be found in the subjective attitude of the observer. We instructed our observers that they should judge whether the second stimulus presented in each pair was subjectively lighter, equal or heavier than the first. On the basis of our questioning, however, we believe that this subject did not accept the above task but set for himself an *Aufgabe* of invariably detecting a difference between the stimuli which were presented to him. For this reason, he approached the problem with a different subjective attitude from that of the other subjects,—a difference in attitude which would account for his anomalous results.

Another feature becomes evident when we compare subject IV.'s interval of uncertainty for the first two subgroups with his interval of uncertainty for the last three subgroups. The fact that the employment of a two-gram interval between the comparison stimuli gave markedly greater values of the interval of uncertainty indicates clearly that the size of the interval between the comparison stimuli has a profound inverse influence upon the size of the interval of uncertainty. Our present data are not sufficiently extensive to justify us in making positive assertions regarding this inverse influence, but they do justify us in emphasizing the importance of this phenomenon as a problem for future research. If in the light of such research, this inverse influence proves to be a genuine

[1] F. M. Urban, 'The Application of Statistical Methods to the Problems of Psychophysics,' Philadelphia, 1908, 106ff. F. M. Urban, 'The Method of Constant Stimuli and its Generalizations,' Psychol. Rev., XVII., 1910, 229–259.

finding, it must clearly be regarded as indicating an inadequacy of the method of constant stimuli.[1]

The above results and discussion may be summarized as follows:

1. The subjective attitude with which the subject approaches the problem in lifted weights, or the *Aufgabe* which he sets himself, has a profound influence upon the size of his interval of uncertainty.

2. In an extended study by the method of constant stimuli, it is possible to eliminate the two extreme intensities of the comparison stimuli from the classical arrangement of seven pairs, without thereby affecting the values either of the measure of sensitivity or of the point of subjective equality to any marked extent. In a former study we showed that this statement holds upon the basis of purely formal considerations; and our present study verifies these earlier theoretical findings upon the basis of psychological experimentation. For the trained subjects the effect of the elimination of the two extreme intensities is slightly less than it is for the untrained subjects. But in either case the differences between the extended and the reduced series as regards the value of the measure of sensitivity and the point of subjective equality are so small that they may be entirely disregarded. Moreover, when we average the final values which were obtained for all of our subjects, we find that these differences tend to disappear almost entirely.

3. The elimination of the two extreme intensities of the comparison stimuli from the classical series employed with the method of constant stimuli obviously reduces the time and labor necessary for the accumulation of an adequate body of data by nearly one third.

[1] Since writing this paper, we find that the same fact has been noted by Warner Brown in the case of the ascertaining of the stimulus threshold for salt sensations. The Judgment of Very Weak Sensory Stimuli with Special Reference to the Absolute Threshold of Sensation for Common Salt. *University of California Publications in Psychology*. I., No. 3, 1914, 229–235.

A STUDY OF THE EFFECT OF BASKET BALL PRACTICE ON MOTOR REACTION, ATTENTION AND SUGGESTIBILITY[1]

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Statement of the Problem

Much discussion has been published within recent years as to the probable value of *athletics* for college students, especially certain forms of exercise as that of *foot ball* and *basket ball.* In this connection it occurred to the writer that by singling out certain physical and mental traits it would thus be possible to reduce the problem to a measurable basis. Accordingly the physical trait of *motor reaction* and the psychical traits of *attention* and *suggestibility* were selected as those which might reasonably be expected to show change through basket ball practice when persistently followed up for a season.

Questions Around which the Outcome of the Experiment Seemed to Center

Does persistent practice at basket ball affect the subject in respect to rate of *voluntary movement* and in respect to *involuntary control?*

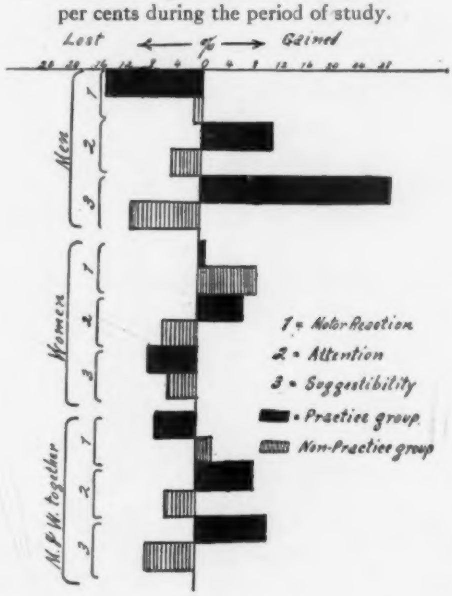
Is persistent practice at basket ball conducive to more, or less, power to concentrate *attention?*

Is the effect of this kind of exercise, when persistently carried out, such as to render the subject more, or less, susceptible to influence by *suggestion?*

[1] The experimental work represented in this study was performed in the laboratory of the educational clinic at the University of Puget Sound during the winter of 1912-13. In this connection acknowledgment is due the five members of my class, who elected the course in clinical work, for assistance in tabulating the data and evaluating same: also, to Dr. Frederick E. Bolton, dean of the school of education, of the University of Washington, for valuable advice and suggestions while carrying on the experiment as well as for assistance in the preparation of the material for publication.

These were the specific questions which it was thought the experiment should answer directly. Of course the more general question as to the desirability of any particular form of the traits mentioned, as that of *fast* or *slow* motor movement, ability to *concentrate* attention, or *susceptibility* to influence through suggestion, while no doubt more important in a broader consideration of the problem, were nevertheless only incidental to this study.

Chart showing comparative changes in per cents during the period of study.



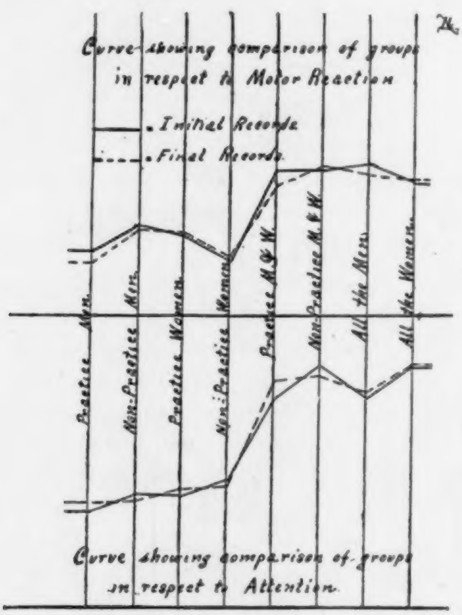
Subjects Coöperating

On the grounds that the element of coöperation would lend increased interest and hence add reliability to the data to be obtained, the proposed experiment was made known in a general way to the student body and volunteers were called for from which twelve, of as nearly equal ability as possible, were selected. The subjects were so chosen that they constituted four groups of three members each, arranged on the basis of sex, and also on the basis of their participating in basket ball, so that we had a practice and a non-practice group

of men and likewise a practice and a non-practice group of women.

Conditions of the Experiment

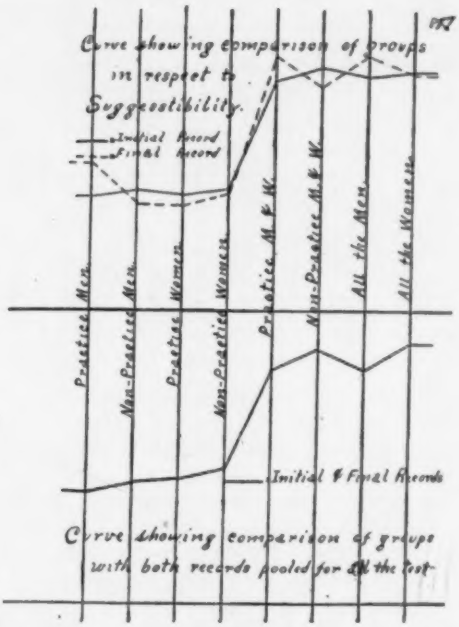
All the tests were conducted under conditions as nearly uniform as possible, those on *attention* being performed in class without disturbance or distraction, while those on *motor reaction* and *suggestibility* were done in the clinical laboratory.



A trained assistant was always in attendance in order to insure the utmost care in securing and recording the data.[1] The tests were all given at the very beginning of the basket ball season and then again three months later at the close of the study. Sufficient explanation and preliminary practice were allowed in order to work off curiosity so that each subject was in condition to do his best when the tests were given for the experiment. No visitors were allowed. In all the tests

[1] Acknowledgment is due in this respect to Miss Helen Lynwood Vent for her painstaking care throughout the experiment, who labored as an assistant in the laboratory without special remuneration for almost two years.

standard materials and apparatus were used, the same having been procured from C. H. Stoelting Co., of Chicago. Since all the tests used are found described in detail in Whipple's 'Manual of Mental and Physical Tests' it will be sufficient to



omit detailed description in this article and simply refer to them by number.

KEY TO THE FOLLOWING TABLES

No.	Sex	Name	Age	Group	Trait	Name of Test Used	No. in Whipple's Manual
1	M	Bem	20	Practice	Motor	Rate of movement, Tapping	10
2	M	Wit	22	Practice	Reaction	Steadiness, Involuntary Movement	12
3	M	Hor	20	Practice			
4	M	Hus	30	Non-Pr.		Cancellation, letter 'a'	26-*A*
5	M	Gen	35	Non-Pr.	Attention	Cancellation, letter 'q, r, s, t'	26-*B*
6	M	Buk	23	Non-Pr.	and	Cancellation, words with 'a, t'	26-*C*
7	W	Fog	26	Practice	Perception	Cancellation, Misspelled words	26-*D*-1
8	W	Bon	23	Practice		Cancellation, Misspelled words	26-*D*-2
9	W	Jon	24	Practice		Simultaneous Adding	29
10	W	Lan	23	Non-Pr.			
11	W	Sur	25	Non-Pr.	Suggestibility	Progressive Weights Illusion	41
12	W	Log	20	Non-Pr.		Progressive Lines Illusion	42

Table I

Test No. 10

Table Showing Record of all the Subjects in Respect to *Motor Movement*, as Measured by the Tapping Test

No.	(1) At the Beginning of the Study					(2) At the Close of the Study				
	A	*B*	*S*	*HI*	*E*	*A*	*B*	*S*	*HI*	*E*
1	7.2	6.5	6.9	.9	6.2	6.3	5.5	5.9	.9	5.2
2	7.7	6.3	7	.8	5.7	7.8	6.7	7.3	.9	6.2
3	6.6	5.8	6.1	.9	5.4	6.6	5.7	6.2	.9	5.3
4	6	7.9	6.9	1.3	9.1	7	6.6	6.8	.9	6.7
5	7	5.6	6.3	.8	5	8.7	6.7	7.7	.8	5.9
6	7.8	6.4	7.1	.8	5.8	7.3	6.6	6.9	.9	6.4
7	6.5	5.6	6	.9	5.2	6.9	6.5	6.7	.9	6.3
8	6.1	4.8	5.5	.8	4.2	6.4	5.3	5.8	.8	4.9
9	7.3	7.3	7.3	1	7.3	7.5	7.5	7.5	1	7.5
10	6.7	6	6.3	.9	5.7	6.9	6.5	6.7	.9	6.2
11	7.4	6.7	7.1	.9	6.4	6.8	6.2	6.9	.9	6.2
12	5.9	4.9	5.4	.8	4.4	5.9	4.9	5.4	.8	4.4

Rate of Motor Movement, as determined by tapping. Standard tapping board used, with kymograph for recording. Results based upon two trials each for the right and left hand over a period of twelve seconds. Own formula devised for evaluating data.

While the weakness of this formula is recognized, as is illustrated by reference to subject No. 4 in the first test, in which case the average number of taps for the left hand exceeds that for the right hand, yet it is believed that the correlation between the right and left hand should figure in the final index of efficiency in tests of this kind. Besides, this apparent weakness in the formula proposed may be obviated by reciprocating the term *B* over *A* in such cases as the one cited, or better still, by changing the formula to read *HI* equals the lesser term over the greater term. The following formula has been devised for this test:

A equals the average number of taps for the right hand. *B* equals the average number of taps for the left hand. *S* equals speed, when *S* equals *A* plus *B*, over 2. *HI* equals index of correlation, when *HI* equals *B* over *A*, or as suggested above, the lesser average over the greater average. *E* equals index of coefficiency, when *E* equals *HI* times *S*.

Table II

Test No. 12

Table Showing Record of All the Subjects in Respect to *Motor Control*, as Measured by the Steadiness Test

No.	(1) At the Beginning of the Study				(2) At the Close of the Study			
	A	*B*	*S*	*E*	*A*	*B*	*S*	*E*
1	62	69	65.5	34.5	11	28.5	19.8	80.2
2	35	45.6	40.3	59.7	111	126	118.5	—18.5
3	6.5	13.5	10	90	5	7	6	94
4	2	2	2	98	1	1	1	99
5	3.5	13.5	8.5	91.5	4	3	3.5	96.5
6	18.5	16.5	17.5	82.5	15	11.5	26.5	73.5
7	11	25	18	82	9.5	26.5	18	82
8	13.5	34.5	24	76	16.5	29	22.7	77.3
9	20.5	11	15.7	84.3	15	19.5	17.2	82.8
10	26.5	43	34.8	65.2	15	37	26	74
11	15	10.5	12.8	87.2	6.5	8.5	7.5	92.5
12	108	84	96	4	108	84	96	4

Steadiness of Motor Control, as determined by involuntary movement. Standard steadiness tester used, with kymograph for recording. Results based upon two trials each for the right and left hand, through holes No. four to No. seven inclusive, over a period of twelve seconds. Own formula devised for evaluating data, as follows:

A equals average number of errors for the right hand. *B* equals average number of errors for the left hand. *S* equals steadiness, when *S* equals *A* plus *B*, over 2. *E* equals index of coefficiency, when *E* equals 100 − *S*.

In this formula the correlation between the right and left hand is not taken into consideration as was the case in test number 10, still a careful comparative study of the two tables does not argue in favor of the omission.

Table III

Test No. 26 *A*

Table Showing Record of All the Subjects in Respect to *Degree of Attention*, as Measured by Cancellation of the Letter 'a'

No.	(1) At the Beginning of the Study						(2) At the Close of the Study					
	O	*C*	*W*	*S*	*A*	*E*	*O*	*C*	*W*	*S*	*A*	*E*
1	0	35	0	911	1	911	0	44	0	1,086	1.	1,086
2	0	27	0	776	1	776	3	35	0	1,100	.92	1,012
3	1	32	0	877	.97	850	2	34	0	985	.94	930
4	1	43	0	1,215	.98	1,191	4	46	0	1,325	.92	1,229
5	1	37	0	1,080	.97	1,048	1	39	0	1,100	.98	1,073
6	9	37	0	1,215	.8	972	4	39	0	1,170	.91	1,072
7	4	30	0	900	.88	794	2	33	0	945	.94	888
8	0	38	0	1,057	1	1,057	0	50	0	1,325	1	1,325
9	10	48	0	1,282	.8	1,063	0	46	0	1,215	1	1,215
10	0	44	0	1,086	1	1,086	3	46	0	1,310	.94	1,329
11	2	44	0	1,215	.96	1,166	2	44	0	1,225	.96	1,172
12	0	50	0	1,327	1	1,327	0	50	0	1,327	1	1,327

Degree of Attention, as determined by cancellation of the letter 'a' from a printed text containing type set in chance order. Standard printed forms used.

Formula taken from Whipple's Manual, as follows: *O* equals the number of letters omitted. *C* equals the number of letters cancelled. *W* equals the number of letters wrongly cancelled. *S* equals the number of letters covered. *A* equals the index of coefficiency, when *A* equals *C* minus *W*, over *C* plus *O*. *E* equals efficiency, when *E* equals *S* times *A*, or when *E* equals *S* over *A*.

Table IV

Test No. 26 *B*

Table Showing Record of All the Subjects in Respect to *Degree of Attention*, as Measured by Cancellation of the Letters 'q, r, s, t'

No.	(1) At the Beginning of the Study						(2) At the Close of the Study					
	O	*C*	*W*	*S*	*A*	*E*	*O*	*C*	*W*	*S*	*A*	*E*
1	12	95	0	679	.89	603	15	128	0	870	.90	783
2	11	80	1	594	.87	516	27	75	0	680	.74	500
3	4	81	0	559	.96	531	5	82	0	573	.94	539
4	16	144	0	1,016	.90	914	18	125	0	870	.87	757
5	28	106	0	830	.79	657	10	101	0	700	.83	581
6	29	95	0	79	.77	604	35	68	0	650	.66	394
7	52	94	0	931	.64	588	7	96	0	670	.93	623
8	30	95	0	800	.76	608	15	100	1	700	.86	602
9	40	99	0	832	.71	591	27	101	1	730	.82	527
10	30	38	0	1,066	.86	919	21	102	0	770	.83	639
11	18	124	0	893	.87	780	11	107	0	731	.88	645
12	22	111	0	838	.83	693	22	111	0	838	.83	693

Degree of Attention, as determined by cancellation of the letters 'q, r, s, t' from a printed text containing type set in chance order. Standard printed forms used. Formula taken from Whipple's 'Manual,' being the same as that used in test 26 *A*.

Table V

Test No. 26 *C*

Table Showing Record of All the Subjects in Respect to *Degree of Attention*, as Measured by Cancellation of Words Containing 'a and t'

No.	(1) At the Beginning of the Study						(2) At the Close of the Study					
	O	*C*	*W*	*S*	*A*	*E*	*O*	*C*	*W*	*S*	*A*	*E*
1	1	29	0	190	.96	184	2	32	1	190	.95	181
2	3	17	0	152	.85	129	7	22	1	198	.72	143
3	1	17	0	135	.94	126	2	22	0	164	.92	150
4	1	33	0	250	.97	243	2	32	1	190	.95	181
5	0	21	0	155	1	155	3	30	0	249	.90	224
6	1	26	0	190	.96	182	2	26	0	178	.93	165
7	6	18	0	164	.75	123	3	21	0	207	.88	181
8	0	28	0	200	1	200	2	35	0	259	.95	246
9	5	32	0	258	.87	222	5	31	0	224	.86	193
10	0	36	0	261	1	261	4	41	0	291	.91	271
11	4	28	0	260	.87	226	3	32	0	241	.91	219
12	0	30	0	198	1	198	0	30	0	198	1.00	198

Degree of Attention, as determined by cancellation of words containing the letters 'a and t' from a Spanish text. Standard printed forms used. Formula taken from Whipple's 'Manual,' being the same as that used in test 26 *A*.

Table VI

Test No. 26 *D*–1

Table Showing Record of All the Subjects in Respect to *Degree of Attention*, as Measured by Cancellation of Mis-spelled Words

No.	(1) At the Beginning of the Study						(2) At the Close of the Study					
	O	*C*	*W*	*S*	*A*	*E*	*O*	*C*	*W*	*S*	*A*	*E*
1	9	89	1	397	.90	357	8	75	1	335	.89	298
2	32	48	1	285	.59	168	14	51	1	250	.77	193
3	8	75	1	335	.89	298	12	55	0	250	.82	205
4	11	89	2	405	.73	296	5	62	0	272	.93	252
5	17	29	0	109	.63	69	12	27	0	170	.69	117
6	40	60	1	405	.59	240	40	43	1	318	.51	191
7	9	91	1	405	.90	365	4	72	1	294	.93	279
8	18	82	0	405	.82	332	5	65	0	282	.93	268
9	10	90	1	405	.89	361	12	91	3	392	.85	340
10	20	80	1	405	.79	320	17	64	1	315	.79	249
11	28	72	1	405	.73	296	8	58	1	257	.86	128
12	8	73	0	349	.90	314	8	73	0	349	.90	314

Degree of Attention, as determined by cancellation of mis-spelled words from English text. Standard printed forms used. Formula taken from Whipple's 'Manual,' being the same as that used in test 26 *A*.

Table VII

Test No. 26 *D*–2

Table Showing Record of All the Subjects in Respect to *Degree of Attention*, as measured by Cancellation of Mis-spelled Words

No.	(1) At the Beginning of the Study						(2) At the Close of the Study					
	O	*C*	*W*	*S*	*A*	*E*	*O*	*C*	*W*	*S*	*A*	*E*
1	6	64	0	290	.91	206	5	54	0	234	.91	213
2	3	43	1	183	.91	167	22	43	2	265	.65	172
3	5	54	0	234	.91	213	13	75	0	350	.85	298
4	2	72	0	305	.97	296	2	77	1	321	.96	309
5	13	21	0	127	.62	79	19	27	0	171	.59	100
6	20	54	0	305	.73	223	35	51	0	336	.59	199
7	2	72	1	305	.96	293	0	78	1	309	.99	306
8	8	61	3	277	.84	233	10	70	3	318	.84	266
9	10	90	2	396	.88	246	9	93	2	400	.90	360
10	10	51	2	252	.80	202	10	68	1	320	.89	284
11	5	54	0	234	.91	213	5	58	0	250	.92	230
12	11	48	0	234	.81	190	11	48	0	234	.81	190

Degree of Attention, as determined by cancellation of mis-spelled words in English text. Standard printed forms used. Formula taken from Whipple's 'Manual,' being the same as that used in test 26 *A*.

TABLE VIII

TEST No. 29

TABLE SHOWING RECORD OF ALL THE SUBJECTS IN RESPECT TO *Degree of Attention*, AS MEASURED BY THE SIMULTANEOUS ADDING TEST

No.	(1) At the Beginning of the Study								(2) At the Close of the Study							
	A	*B*	*A'*	*C*	*S*	*W*	*E*	*C'*	*A*	*B*	*A'*	*C*	*S*	*W*	*E*	*C'*
1	33	18	15	24	90	0	90	1.2	38	18	17	29	102	0	102	1.2
2	32	21	18	24	95	1	85	1.1	36	15	12	26	89	0	89	1.2
3	37	19	15	26	97	0	97	1.2	48	12	15	23	98	0	98	1.8
4	54	39	18	32	143	3	113	1	51	18	18	46	133	3	103	1.1
5	25	22	6	14	67	4	27	.9	35	11	12	21	79	5	29	1.5
6	21	12	10	18	61	1	51	1	24	9	12	12	57	0	57	1.7
7	29	18	11	18	76	1	66	1.1	45	18	6	24	93	1	83	1.2
8	30	18	15	23	86	1	76	1.1	30	9	9	20	68	0	68	1.3
9	36	30	11	15	92	2	72	1.1	45	12	19	24	100	7	30	1.9
10	39	18	15	22	94	2	74	1.3	39	18	18	29	94	1	84	1.2
11	26	17	6	13	62	0	62	1.1	24	16	9	16	65	2	45	1
12	33	22	6	26	87	0	87	.8	33	22	6	26	87	0	87	.8

· Degree of Attention, as determined by simultaneous adding of three columns of figures. Standard printed forms used. Own formula devised, and adaptation of method. Results based upon adding 'Signal A' for one minute, 'Signal B' for one half minute, 'Signal A' again for one half minute, and then 'Signal C' for one minute.

The following formula has been devised for this test, viz: Signal A equals 1, 2, 3. Signal B equals 2, 3, 1. Signal C equals 3, 1, 2. *A* equals the number of additions of signal A. *B* equals the number of additions of signal B. *A'* equals the number of additions of signal *A* the second time. *C* equals the number of additions of signal C. *S* equals the total number of additions. *W* equals the number of errors. *E* equals the index of efficiency, when *E* equals *S* minus 10 times *W*. *C'* equals consistency, when *C'* equals *A* plus *A'*, over *B* plus *C*.

An effort has been made to adapt this form of Attention test to the games of Foot-Ball and Basket Ball and also to eliminate some of the objectionable features when given according to the instructions in Whipple's 'Manual.' First of all the figures 1, 2, and 3 were arranged in different orders and styled 'Signal A' 1, 2, 3; 'Signal B' 2, 3, 1; and 'Signal C' 3, 1, 2. These signals were first explained and memorized after which they were called out in various orders by the instructor for practice. Then in order to insure against loss of time in case some one should fail to be able to recall the proper signal when given in the test, the subject was allowed to write the signals at the top of the record sheet. In order to eliminate as far as possible the element of immediate memory, which is offered as an objection by Professor Whipple, the numbers were left uncovered after each successive addition, instead of being covered immediately as directed in the manual. When all was fully explained and comprehended by the subject, the instructor announced (just as is done in the game) 'Signal!' (which always means, Attention!) then 'A!,' at which the subject quickly turned his paper right side up and proceeded to add 'Signal A,' *i. e.*, 1, 2, 3, respectively to the numbers found printed at the top of the columns on the record sheet. This was kept up until the instructor announced another signal, whereupon the subject proceeded immediately to add this signal, and so on until the test was completed as mentioned above.

It is believed that this adaptation of the simultaneous adding test will practically eliminate the element of immediate memory and thus provide a test which will measure directly the ability to concentrate attention. It will not, however, serve as an absolute test of the ability of different individuals to concentrate Attention, since the number of additions that any individual performs is not in itself an index of such ability. On the other hand, it does seem reasonable that the difference in the number of additions performed by the same individual at different trials may be attributed to the difference in his concentration of attention, hence the trait of degree of attention in a given individual may be measured in a comparative way by the simultaneous adding test, when the element of immediate memory is eliminated.

Table IX

Test No. 41

Table Showing Record of All the Subjects in Respect to *Suggestibility*, as Measured by the Progressive Weights Illusion

No.	(1) At the Beginning of the Study						(2) At the Close of the Study					
	A	*B*	*C*	*A'*	*S*	*S'*	*A*	*B*	*C*	*A'*	*S*	*S'*
1	7.4	5.2	1.4	.44	20	85.91	8.8	4.4	.8	.48	20	88.75
2	6.8	5.4	1.8	.43	20	88.11	5.9	6.3	1.8	.38	20	80.79
3	6.2	5.4	2.4	.43	20	85.11	7.4	3	3.6	.55	20	92.73
4	9.8	3	1.2	.55	20	92.73	10	4	0	.50	20	90
5	8.8	4.6	.6	.47	20	88.09	8.6	4.6	.8	.47	20	88.09
6	8	4.6	1.4	.47	20	88.09	8.2	4.4	1.4	.48	20	88.75
7	12.8	1.2	0	.62	20	96.45	6	7.4	.6	.33	20	74.55
8	10.8	3.2	0	.54	20	92.23	11.6	2.4	0	.58	20	94.14
9	10	3.2	.8	.54	20	92.23	9.8	3.4	.8	.53	20	91.70
10	7	6.8	.2	.36	20	78.33	5.8	7.6	.6	.32	20	73.13
11	7.2	5.2	1.6	.44	20	85.91	7.8	4.8	1.4	.46	20	87.39
12	6.2	6.6	1.2	.37	20	79.56	6.2	6.6	1.2	.37	20	79.56

Suggestibility, as determined by progressive weights illusion. Standard set of fifteen weights used. Results based upon five trials each hand. Own formula devised for evaluating data, as follows: X equals weight of first stimulation weight. Y equals the weight of the last stimulation weight. Z equals the number of stimulation weights, S equals the force of the stimulation, when S equals Y over X, times Z, minus Z.

It is believed that this formula will be found reliable for estimating the force of the stimulation used in tests of this kind even when the ratio of the stimulation weights, or the number of stimulation weights, varies from that used in this test, *e. g.*, if the stimulation weights were given as 20, 40, 80, 160, 320, the force of the stimulation would figure 75. If the series were given as 20, 40, 60, 80, 100, 120, 140, the force of the stimulation would figure as 42; whereas in the test as given the series is 20, 40, 60, 80, 100, hence the force of the stimulation figures 20.

Having thus determined the force of the stimulation, which of course remains constant throughout the experiment, the following formula has been devised for further evaluating the data: A equals the average number of plusses. B equals the average number of equals. C equals the average number of minuses. A' equals the index of coefficiency, when A' equals A plus C, over S. S' equals suggestibility, when S' equals 100 minus 1 plus B, over A.

Below is given a somewhat more elaborate formulation of this method, which is based upon the following theory of reaction. First, when any series of stimulation, as that of progressive weights, is applied, the effect of same upon the subject is shown by a major wave of reaction followed by several minor waves. Second, the major wave is represented by the number of consecutive plusses that follows the last stimulation weight, while the minor waves are represented by all the plusses and minuses that follow in the series subsequent to the end of the major wave. Third, the amount of resistance offered by the subject is represented by the number of equals recorded subsequent to the last stimulation weight. The formula based upon the above theory is as follows: *A* equals the number of consecutive plusses beyond the last stimulation weight. *B* equals the number of equals subsequent to the last stimulation weight. *A′* equals the number of plusses beyond *A*. *C* equals the number of minuses beyond *A*. *S* equals the force of the stimulation (determined by the formula given above). *E* equals the index of coefficiency, when *E* equals *A* over *S*. *E′* equals the minor index of coefficiency, when *E′* equals *A′* plus *C*, over 1 plus *B*. *S′* equals suggestibility, when *S′* equals 100 minus *E* times (*E′* plus 1).

Table X

Test No. 42

Table Showing Record of All the Subjects in Respect to *Suggestibility*, as Measured by the Progressive Lines Illusion

No.	(1) At the Beginning of the Study				(2) At the Close of the Study			
	S	*A*	*B*	*S*	*S*	*A*	*B*	*S*
1	20	49.8	114.4	38.1	20	33.5	293	97.7
2	20	49.5	160.4	53.4	20	49	205.2	68.4
3	20	51.9	70.6	23.5	20	47.5	163	54.3
4	20	54.5	118.5	39.3	20	45.5	64	21.3
5	20	55	94.3	30.1	20	40	16.7	5.4
6	20	51	163.6	54.5	20	38.5	176	58.7
7	20	45.5	108.5	36.2	20	49	64.7	24.4
8	20	54.0	80.4	26.8	20	53	83.5	27.8
9	20	45	105.2	35.1	20	50	111.5	37.1
10	20	58	231.7	77.2	20	58.5	30.5	10.2
11	20	60	74.3	24.8	20	55	237.7	79.2
12	20	45	161.7	53.9	20	45	161.7	53.9

Suggestibility, as determined by progressive lines illusion. Standard set of lines used. Records made on graph paper. Results based upon two trials through exposure of 21 lines beyond the last stimulation line. Own formula devised for evaluating data, as follows: *X* equals length of first stimulation line. *Y* equals the length of the last stimulation line. *Z* equals the number of stimulation lines. *S* equals the force of the stimulation, when *S* equals *Y* over *X*, times *Z*, minus *Z*. *A* equals estimated length, by the subject, of the last stimulation line. *B* equals the aggregate error in millimeters both ways, from the standard *A*, made by the subject in the entire series subsequent to the last simulation line. *S′* equals suggestibility, when *S′* equals the term sought in the equation *Y* over *S* equals *B* over *S′*.

The charts here mentioned appear on pp. 357, 358 and 359 and are properly labelled there.

Results Obtained from the Experiment

During the three months covering the period of the study the following changes took place in the *motor reaction*, *attention* and *suggestibility* of the subjects under consideration, as determined by the ten different tests employed.

The *practice* group of men lost 14.9 per cent. in *motor reaction*, gained 10.8 per cent. in *attention* and gained 29.6 per cent. in *suggestibility*.

The *non-practice* group of men lost 1.3 per cent. in *motor reaction*, lost 4.4 per cent. in *attention* and lost 10.3 per cent. in *suggestibility*.

The *practice* group of women gained .7 per cent. in *motor reaction*, gained 7 per cent. in *attention* and lost 7.7 per cent. in *suggestibility*.

The *non-practice* group of women gained 8.3 per cent. in *motor reaction*, lost 4.9 per cent. in *attention* and lost 4.1 per cent. in *suggestibility*.

The *practice* men and women taken together lost 6.1 per cent. in *motor reaction*, gained 8.8 per cent. in *attention* and gained 10.9 per cent. in *suggestibility*.

The *non-practice* men and women taken together gained 2.2 per cent. in *motor reaction*, lost 4.7 per cent. in *attention* and lost 7.2 per cent. in *suggestibility*.

All the men taken together lost 6.9 per cent. in *motor reaction*, gained 2.6 per cent. in *attention* and gained 9.3 per cent. in *suggestibility*.

All the women taken together gained 3.8 per cent. in *motor reaction*, gained .6 per cent. in *attention* and lost .7 per cent. in *suggestibility*.

The highest individual record at the beginning of the study was made by men in *four* and by women in *six* of the ten tests.

The highest individual record at the close of the study was also made by men in *four* and by women in *six* of the ten tests.

The lowest individual record at the beginning of the study was made by men in *six* and by women in *four* of the ten tests.

The lowest individual record at the close of the study was made by men in *eight* and by women in *two* of the ten tests.

Pooling all the ten tests given both at the beginning and

at the close of the study and taking this as a basis for measuring the abilities of the subjects in respect to *motor reaction*, *attention* and *suggestibility* all taken together, the *non-practice* men appear 8.2 per cent. stronger than do the *practice* men. The *non-practice* women appear 7.5 per cent. stronger than do the *practice* women. The *non-practice* men and women taken together appear 7.2 per cent. stronger than do the *practice* men and women. All the *women* taken together appear 12.2 per cent. stronger than do the *men*.

Of course in these last comparisons based upon the pooling of all the tests it is to be remembered that *stronger* means a faster rate of, and more steadiness of, *motor control* and a greater degree of ability to concentrate *attention*, but it also means a greater degree of susceptibility to influence through *suggestion*.

Some Conclusions Drawn from the Foregoing Study

In a general way the study seems to warrant, in a measure at least, the following conclusions, to wit:

The persistent practice of basket ball for a season of three months has the tendency to break up control of *motor reaction* by reducing the *rate* of voluntary movement and rendering the subject *less steady* in point of involuntary movement. But at the same time such exercise has the tendency to *increase* the subject's power to concentrate *attention*, as well as to render him *more susceptible* to influence through *suggestion*.

Considered on the basis of sex, the persistent practice of basket ball appears to affect *men*, in respect to *motor reaction*, *negatively* MORE than it does *women*. In respect to *attention*, the *men* are affected, *positively*, MORE than are the *women*. In respect to *suggestibility*, the *men* are affected, *positively*, VERY MUCH MORE than are the *women*.

This difference in the degree of effect shown upon the *men* when compared with the *women* is no doubt partly due to the fact that as a rule men play the game much harder than do the women. This fact is obvious for two reasons, first, we may say, because of the natural difference in the activity of men and women and second because of the limitations set upon the

activity of women by the restrictive rules for women's basket ball games.

It should be said with reference to the conclusions herein stated that they are rendered rather more conservative than they might otherwise have been by the fact that one of the non-practice women, namely, subject No. 12, was obliged to drop out on account of illness, hence her record for the close of the study being wanting was necessarily supplied. Since this was done by duplicating her record made at the beginning of the study, it would tend to reduce the differences shown between the *practice* and the *non-practice* women, assuming of course that this subject would have shown changes in a general way similar to the other two members of the non-practice group.

As measured by the tests used in this experiment it appears that *men* are superior in respect to *motor reaction*, while the *women* are superior in point of *attention*, and less *suggestible* than are the men.

Assuming that the average person is quite *suggestible* enough, it would appear that persistent practice at basket ball is *un*desirable.

Again, assuming that increased ability to concentrate *attention* is to be desired, it would appear that persistent practice at basket ball *is* desirable.

Finally, assuming that it is *un*desirable to be broken up in point of *motor control*, we would have two points against, with only one in favor of, basket ball as a form of athletics to be recommended to the average college student.

PSYCHOLOGICAL TESTS AS APPLIED TO THE CRIMINAL WOMEN

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The following is the experimental data presented in a twelve-minute paper at the American Psychological Association in December, 1912. The work was begun in July, 1911, under a grant from the New York Foundation and is being carried on at present by the Bureau of Social Hygiene which has established the Laboratory of Social Hygiene at Bedford Hills in affiliation with the New York State Reformatory for Women. The scheme includes ultimately an exhaustive study of the mental and physical history and condition of a large number of criminal women with the hope that, among other things, once the research is ended and tests established, the State of New York will see fit to include in its machinery for dealing with the criminal women a clearance house to which she may be sent after being judged guilty, and from which after examination she may be sentenced more wisely in accordance with her possibilities and needs and not arbitrarily according to her crime. The problem that was in mind in the application of the tests herein reported was a first step toward the formation of a body of tests which could be applied after a woman's conviction and preceding her sentence which should prove a safe guide as to her reformability.

The women sent to us vary in age from sixteen to thirty. The average physical age of the first thousand inmates committed to Bedford was 20.8 years. The average age of the two hundred women reported upon in this paper is 20.47 years.

Upon the apparently universal assumption that the feeble-minded are not reformable nor able to conduct themselves wisely outside of an institution, and because an appreciable per cent. of our girls were obviously feeble-minded, we felt it desirable to determine exactly what this per cent. might be.

For this purpose Dr. Goddard's adaptation of the 1908 Binet series was at hand. Although skeptical of their absolute clinical value for mature women, it seemed advisable to test their serviceableness; for, at the time this work was begun (July, 1911) none of the more recent critical work of the Binet tests had been published. Accordingly the writer gave these tests under the most precise of laboratory conditions to two hundred women as they came to us in sequence from the courts, to find that only .5 per cent. could pass the 12-year-old test and that the average mental age was 10.07 (7.785) years.

2 tested	6 years
15 tested	7 years
13 tested	8 years
47 tested	9 years
74 tested	10 years
48 tested	11 years
1 tested	12 years

Inasmuch as a fair per cent. of this number were bound to prove reformable if the practical experience of the institution was to be relied upon, we must needs conclude either that the feeble-minded were reformable or that the tests, at least as applied to the criminal woman, were inadequate.

Moreover, we have since tested, with the aid of Dr. Mabel R. Fernald, twenty-five girls in the Chicago Normal School (A, B and C students in psychology) and of these, too, not a few failed to pass some proportion of the 9-, 10-, 11- and 12-year-old tests, and have an average age of 11.49 (9.18) years.

In addition, I have given these tests to a group of the more intelligent maids at the University of Chicago and at Vassar College, selecting those who had worked steadily and efficiently in one or the other of these places for at least five years, to find that they average only 10.75 (8.2) years by these tests.[1]

Obviously Goddard's adaptation of the Binet tests, in which both may often test the same, does not serve to differentiate the efficient working woman from the feeble-minded girl of 10, 11 or 12 mental years. Indeed we are convinced that general intelligence tests, such for instance as the Binet test,

[1] There is in preparation for the press a detailed account of these three groups in their reaction to the Binet tests.

may be interesting as a general index of mental training, but are much less useful among the women of whom I speak than motor coördination tests. The Binet tests fail on the one hand because there are a fair proportion of our inmates who are not mentally inefficient but mentally inert. Their lives and minds are so constituted that they feel no need to learn the things 'any child ought to know' though they can and do learn when we teach them. Take for example such a test as Binet's definition of the three abstract terms, 'charity,' 'justice' and 'kindness.' If two of the three are not defined by the child of 12 it may be fairly indicative that he is unable to handle abstract terms. Of our group while only 35 per cent. know the meaning of 'charity' and 44 per cent. say they have never heard the word 'justice,' 96 per cent. can define adequately such words as 'kindness,' 'meanness' and 'goodness.' They will tell you for instance that goodness is a matter of character. It is obviously unfair to assume that because they cannot define two abstract terms the power to think abstractly is denied them.

On the other hand, these general intelligence tests fail to make out as subnormal certain girls of whom we have not a few, who in general information are entirely normal but who are otherwise constitutionally unfit, whose voluntary control is poor, who are easily distracted and emotionally unstable.

The tests that may better be expected to separate the stable, reliable woman from the irreformable one are those that simulate the jobs at which they must earn their livings,—that are simple enough as to directions so the dullest girl can follow them, that demand continuous and continued attention and some patience and nervous resistance.

Such a test, for instance, is the one reported by Bogardus in the *American Journal of Sociology* in 1911.[1] With an apparatus which imitates amazingly well in miniature the average dangerous factory machine, he tested the relation of fatigue to industrial accidents. We have duplicated the test here to find that where the more dependable woman whom the institution

[1] Bogardus, Emory S., 'The Relation of Fatigue to Industrial Accidents,' *The American Journal of Sociology*, Vol. XVII., Nos. 2, 3 and 4.

selects as the reformable one approximates the normal record, making two thirds as many errors in the second half of the working period as in the first and coming fairly near the normal average of errors (3.87 first half and 8.28 second half), the irreformable girl may make as many as 1,335 errors in the first half and 312 in the second half. They work so inaccurately that the errors from fatigue are completely lost sight of. Each day they have to re-learn the 'operation,' so that more errors are apt to come in the first and less in the second half of the working period. Or, again, they are quite as likely to slowly establish bad habits as to laboriously form good ones, and thus the number of errors per day may increase rather than decrease,—due in no sense to fatigue but to practice!

In general, the mental characteristic most peculiar to the criminal woman as she exists as a type at Bedford is an inexplicable narrowness of her scope of interest. What they know may be in quality entirely mature; in quantity it is almost certain in a very high majority of cases to be but a fragment of the mental content of a normal person of average intelligence. If the quality be normal, the 'quantity' is a matter contingent largely upon the character and persistence of previous experience and the capacity for new habit formation. No problem that is set is more important and nothing more difficult than to establish a means of solving with dispatch in advance how the balance lies between these two 'contingent' factors.

Another interesting characteristic of the majority of these women is their slow and variable reaction time. When tested with the Vernier Chronoscope their visual reaction time is .35 secs.; the auditory reaction time is .20 secs. This superiority of audition is borne out by the fact that they follow spoken directions better than written ones. The mean variation of the reaction time of a normal person after practice is about one tenth of his average reaction time. The mean variation for the criminal woman is seldom less than one fifth of her average reaction time.

This slowness of reaction time is shown both in tests of

motor coördination and association of ideas. When, for instance, they are asked to give the verbal opposite of ten easy words, only .906 per cent. come within the slowest time (1.50 seconds) given by Woodward's subjects in response to his series of easy opposites and only .011 per cent. come within the best time of his subjects (1.03 seconds); only 24.62 per cent. make as few as one error or less; 60 per cent. make more than one error but less than six errors and failures taken together, 15.38 per cent. as many as five or more failures. (A failure all wrong; an error a response that is partly right.)

If asked to say as many words as they can in three minutes, only 47 per cent. can succeed in saying as many as 60.

With the Jastrow card-sorting apparatus, only one out of two hundred girls comes within the slowest time made by the twenty-five university girls tested by Dr. Thompson.[1] To measure their ability to learn a simple motor coördination by five trials of tracing a star in a mirror, is to find that whereas twenty-three college women tested by Whipple take 127 seconds for the first and 67 seconds for the last trial, a consecutive series of fifty of our girls take on the average of 485.72 seconds for the first trial and 117.53 seconds for the last trial; also that whereas his women make 34 errors the first trial, ours make 190.08 with 46.15 errors in the last trial.

Only 9 per cent. can repeat more than seven numbers after hearing them spoken; 47.5 per cent. can repeat seven numbers; 28.5 per cent. only six and 25 per cent. less than six. Only 11.5 per cent. can repeat after one a sentence containing 26 syllables; 81.8 per cent. are unable to repeat a sentence containing 24 syllables.

After reading a passage containing 25 unit words and phrases, 79.87 per cent. remember less than half, and 54.54 per cent. remember less than 10 units. This passage can be read comfortably in 14 seconds. The best 11.5 per cent. of our women take on the average 15.9 seconds to read it. 12.5 per cent. cannot read in any language and 11 per cent. cannot write in any language.

[1] Thompson, Helen B., 'Psychological Norms in Men and Women,' The University of Chicago Contributions to Philosophy, Vol. IV., No. 1.

These delayed reaction times; this narrowness of memory span; this failure to sort cards and learn to draw stars in the mirror, etc., as well as college women can do them, may to a certain extent be true also of the normal [efficient + law-abiding] working girl and woman. At least until we have tested these latter we cannot say that our women are subnormal. The possibility is that many of them are; but the chances are likewise very great indeed that the records of the better 40 per cent. of the criminal women will be in most respects like the normal working women's, and that both will be appreciably below those of the college girl in quantity and rate—if not in quality.

Our most imperative need in the field of mental tests as applied to the criminal woman is the determination of norms, the determination, at least, of the lowest and the average degree of intellectual capacity and motor control which a law-abiding woman must possess to earn a living.

In conclusion, it may be of incidental interest to add that none of these women are found to be color-blind; that 5.6 per cent. are left-handed, 3 per cent. are ambidextrous, 3 per cent. tattooed, 4 per cent. unmistakably insane, and 15 per cent. addicted to morphine or other drugs.

THE FUNCTION OF INCIPIENT MOTOR PROCESSES

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The construction of an hypothesis can never give the same repose and satisfaction to the scientific conscience as does the discovery of even a moderately significant fact. And hypothesis-building brings with it the less sense of solid accomplishment, the more its results are removed from the actual test of fact. Hence the person who tries to erect a theory as to what occurs in the nervous system, in connection with any processes less amenable to experimental conditions than scratch reflexes, is not likely to feel a gratification proportionate to his pains. And yet a consistent theory of the physiological processes underlying the higher mental processes would be of some practical value, even though it could not be tested by physiological experiment. For a coherent presentation of the facts demands some principle of explanation, and the laws of learning, which lie at the bottom of the complexer processes of mind, suggest certain physiological assumptions which logically demand to be followed out and elaborated into a complete physiological theory.

The present paper aims to suggest an hypothesis regarding the nature of some essential features in the nervous process underlying the production of a mental image, a revived or centrally excited mental process. Since the leading part in such processes, according to this theory, is played by the initiation of movements that are not fully carried out, it may be termed *the theory of incipient motor processes.* As a preliminary to consideration of the image, we may discuss the physiological nature of the associative processes in general.

There are grounds for thinking that to that form of association which has traditionally been called the association of ideas, the association of movements is preliminary. In the so-called association of ideas we have called into consciousness

the image of a past experience. If stimulus *A* and stimulus *B* have at some former time been experienced together, the occurrence of *A* 'makes us think of' *B*; that is, calls up a mental image or centrally excited sensation of *B*. There are two reasons, at least, for believing that a more primitive process than this is to be found in the type of association whereby stimulus *A* comes to produce the *movement* which formerly resulted from stimulus *B*, rather than an *image* of stimulus *B*. These two reasons are as follows. First, among the lower animals we have constant proof that one stimulus may through being repeatedly experienced in connection with another, come to assume the motor tendencies of the other; but we have very limited evidence of the occurrence in the animal mind of the associative production of images. Secondly, in the human mind, the association of images rests absolutely upon attention. Not the fact that the stimuli *A* and *B* occur together gives to *A* the power of calling up an image of *B*, but the fact that the two are attended to together. And whatever else attention may mean, the fact is reasonably certain that simultaneous attention to two things means a simultaneous motor response to them. The dependence of association upon attention, an essentially motor phenomenon, becomes comprehensible if we think of association as being itself primitively an association of movements.

Let us then first consider the processes by which stimuli come to be associated with new movements. We shall use in this consideration four fundamental physiological assumptions, all of which have some warrant from the facts discovered in experiments on simple reflexes.

1. When a motor response is initiated, all the sensory centers[1] that are receiving stimulation at the same time contribute to that response a part of their energy. This is the familiar fact of *Bahnung*, as illustrated by Exner's case of a sound stimulus reinforcing a touch stimulus in producing movement of a rabbit's foot, or by Yerkes's demonstration of the effect of sound stimuli on the reaction of the frog to

[1] I shall use throughout this paper, for convenience, the rather old-fashioned terms sensory and motor *centers*, leaving undetermined whether a center involves one or many neurones.

electrical stimuli.[1] While the principle of Bahnung is usually stated to hold true of certain allied systems of reflexes, we have stated it as a perfectly general principle, with the understanding of course that it may be crossed by other principles.

2. Whenever a sensory center has any part of its energy drained into a motor outlet, the resistances along the path leading to that outlet are decreased. It is unnecessary to dwell upon this assumption. In one form or another, it is indispensable to any theory of the more complex workings of the nervous system.

3. One motor response may be prepotent over others tending to occur at the same time. This prepotency consists in the fact that certain motor responses will be called forth by a much slighter intensity of stimulus than others. For this statement we have the authority of the experimental physiologists, and Sherrington has emphasized the fact that the prepotent responses are those most concerned with welfare.[2]

4. There exist antagonistic motor responses, so connected that the making of one inhibits the making of the other. This statement, also, needs no defence: it is a well-established fact.

To proceed now with our investigation of the process whereby the association of motor processes is brought about, let us suppose two stimuli, *A* and *B*, acting simultaneously upon the organism, and let us suppose further that *A* naturally gives rise to the response *AR* and *B* to the response *BR*. We may further assume that these two responses, *AR* and *BR*, are not antagonistic to each other; that is, that the organism can carry out both movements at once. Now if we have recourse to assumption 1, that when any motor response is made, a portion of the energy of every stimulus acting on the organism at the time is contributed to the making of it, we may assert that a part of the energy of *A* goes to the production of *BR* and a part of the energy of *B* goes to the making of *AR*. If we call assumption 2 also to our aid, whereby the oftener a nervous process travels a certain

[1] See Sherrington, 'The Integrative Action of the Nervous System,' p. 175.

[2] *Op. cit.*, pp. 228–231.

pathway the less the resistance to its passage, we see how the frequent occurrence of *A* and *B* together can give to either *A* or *B* the power of initiating the combined reaction *AR–BR*, without the actual occurrence of the other stimulus. This we may call Type I of motor associations.

In other cases it happens that *AR* and *BR* are not compatible but antagonistic reactions. Now a billiard ball (if I may be pardoned for using that well-worn object as an illustration), when acted upon by two forces in opposite directions is influenced fully by both of them. The weaker loses none of its effect because a stronger one is on the field: it is able to diminish the action of the stronger by the full amount of its own strength. This would be an exceedingly inconvenient principle to govern the actions of a living organism: hence the nervous system works in such a way that the stronger stimulus can wholly suppress and inhibit the movement that would result from the weaker if it acted alone (Assumption 4). This means that if a weak stimulus *A* and a stronger stimulus *B* act together upon the organism, and would if they acted alone demand of it incompatible responses, *A* finds itself quite cut off from its own motor outlet when the motor paths of the response *BR* are open. Hence apparently the whole energy of *A* will be available to find its way into the channels of the response *BR*, according to assumption 1. We might expect that a pathway from *A* to *BR* would be formed with especial rapidity when *BR* and *A*'s original response *AR* are antagonistic. But whatever advantage is derived from the fact that in such a case all *A*'s energies are free to take part in the new reaction is probably compensated for by the fact that the resistances which the energy of *A* has to overcome in finding its way to the antagonistic outlet *AR* are higher than those encountered on the way to a compatible motor response. Indeed it may well be that a part of the very process by which the reaction *AR* inhibits *BR* involves a heightening of the resistances along the paths that would connect *AR* with a stimulus belonging to an antagonistic response. But of course it constantly happens that a stimulus does come to be connected with a reaction the very opposite

of that which originally pertained to it. A tamed animal learns to run to the human being from whom it at first fled in terror. In order that the tendency thus acquired for *A* to produce the response *BR* may be permanent, and may displace its original tendency to produce *AR*, either *B* must occur more frequently with *A* than *A* occurs alone, so that the pathway from *A* to *BR* becomes more permeable with repeated traversing (Assumption 2), or else the response *BR* must be a prepotent response, one that is specially ready to occur provided that even a weak current of excitation reach it (Assumption 4). Such a prepotent response is the negative reaction following harm to the organism, and hence we find that this response readily becomes associated with stimuli that are not in themselves harmful but have been accompanied by injurious stimuli. The type of learning where a stimulus *A* comes to produce a motor response *BR*, opposite in character to its original response *AR*, because of the experiencing of *A* and *B* together, we may call Type II.

Now thus far we have been considering the cases where the two stimuli *A* and *B* act simultaneously upon the organism. But a stimulus *A* may come to produce a response *BR* which originally pertained to another stimulus *B*, when *B* has occurred not together with *A* but immediately after it. The simplest case of this sort will happen when *B* intervenes after the reaction *AR* has been started, but before it has been completed. If *A* is to become associated with the new response *BR*, the latter must draw off into its own channels some of the energy of *A*, and prevent its all being discharged into *AR*. The more natural effect in this case would seem to be for the later stimulus *B* to have all its energy diverted into the already active channels of *AR*, according to Assumption I. To explain how the later response can ever drive the earlier one from the field, we must suppose the later one to be a prepotent response, so ready to occur that even slight excitation will produce it. When *AR* and *BR* are not incompatible reactions, what happens may be simply that *AR* is initiated by the occurrence of *A;* but *B* immediately following and opening the prepotent path *BR*, a part of *A*'s

energy is diverted into *BR*. The oftener this happens, supposing *BR* to be a prepotent response, the slighter is the tendency to produce *AR* at all; thus we have the gradual dropping off of movements which while they are not really antagonistic to the prepotent response, are simply unnecessary, such as the random movements that accompany early attempts at writing or skating, or the aimless struggles of an animal learning to get out of a puzzle box. When, on the other hand, *AR* and *BR* are really antagonistic, we have to suppose that the reaction *BR*, breaking in on the already initiated *AR*, inhibits it not gradually, by depriving it of a part of the energy of its stimulus, but automatically and at once. Thus all the remaining energy of *A* has to find its way into the channels of *BR*. The only difference, it would appear, between these cases, which we may call Types III and IV, where the stimuli are successive and those (I and II), previously considered, where they are simultaneous, is that greater prepotency of one response over the other is demanded for Types III and IV; of the later response over the earlier one, to counteract the advantage of the earlier one in having already got itself started.

Evidently the highest degree of prepotency is required of a reaction that can supplant another which has not only been initiated first, but has actually been carried out. Yet this supplanting does occur in many cases of learning. A stimulus *A* produces its full response *AR:* there follows upon this response a stimulus *B* with its appropriate reaction *BR*. How can *A*, whose energy was wholly used in producing the reaction *AR*, contribute anything to the production of *BR*? The only answer to this question, so far as I can see, lies in the formulation of a further physiological assumption, namely: (5) A certain portion of the energy of a stimulus is left behind after its motor response has occurred, and may be drained into the channels of the next-following motor response. Now for the connection between *A* and *BR*, thus formed through the slight residue of *A* left after the response *AR* has occurred, to become victorious in subsequent experiences over the original response *AR*, and bring it about

that *A* produces *BR* instead of *AR*, it is necessary that *BR* shall have a high degree of prepotency over *AR*. The reaction *BR* in such cases is probably always of the type called by Sherrington 'consummatory reactions,' whose performance is intimately connected with the immediate welfare of the organism. We may call the types of learning which involve the supplanting by another movement of a movement that has actually been carried out, including the two cases, where the movements are antagonistic and where they are not, Types V and VI.

None of these six types of association needs to involve the production of an image or centrally excited mental process, in which the sensory effects of past stimulation are revived. To account for the origin of the image, I should like to propose another physiological assumption, the sixth. It is this: (6) When the cortex has reached a certain degree of development, if a motor response is initiated, all the sensory centers that have recently or frequently discharged into the motor center concerned, that is, all the sensory centers with low resistances at the synapses along the pathways leading from them to the motor center, are set into excitation. This excitation is more marked, and more wide-spread, the greater the delay between the initiation and the execution of the movement. That is, while with a short delay activity will be induced in those sensory centers most closely connected with the motor center concerned, a longer delay will cause the spreading of the induced activity into more remotely connected sensory centers. Upon the activity thus induced in sensory centers, whether near or remote, the image or centrally excited conscious process is based.

The common conception of the process whereby sensory centers are centrally excited, giving rise to images, is that nervous activity passes from one sensory center to another, along a nervous pathway whose resistances have been lowered by the former simultaneous activity of the two centers. Thus there is supposed to be an actual transfer of energy along an associative pathway, just as in the peripheral excitation of a center a transfer of the stimulus energy occurs

along a sensory pathway. The view here proposed maintains, on the other hand, that the discharge of a 'centrally excited' center does not occur by the influx of any energy into it from without. Our theory suggests rather that a discharge of the stored-up energies of the sensory center into a motor center is brought about when the motor center in question is partially excited from another source and the resistances are already low between it and the sensory center whose discharge is thus induced. The process of central excitation would be thus *induced* and not *transferred:* the disturbance of equilibrium in the motor centers draws the stored-up energies from the sensory centers associated with them. It is as if a hitch in the functioning of a motor center enabled it to call to its aid contributions from all the sensory centers connected with it by paths of low resistance. Thus, for example, if in Type I of learning, where the stimulus *A* has become able to produce both its own original response *AR* and the response *BR* which originally pertained to stimulus *B*, the response *BR* is only partly initiated, there will be, supposing the cortex of the animal to have reached the proper degree of development, an induced activity in the sensory center formerly affected by stimulus *B*, with the result in consciousness of an image of *B*.

This theory demands, not that the partial excitation of the motor center *M* shall send a nervous process *to* the sensory centers associated with *M*, which would involve either violating the principle of the irreversibility of synapses or the assumption of a double conduction path; but that the partial excitation of *M* in some way draws a current of excitation down from the associated sensory centers into *M*. While no clear physical or electrical analogy for a process of this sort can be found, we at least contradict no known fact of nervous action by supposing that the excitation of *M* lowers resistances at all the synapses of *M*. This sudden lowering of resistances may be regarded as giving an opportunity for the associated sensory neurones to discharge into *M*. Such an action is assumed by MacDougall to occur in the case of the reciprocal innervation of antagonistic muscles.[1] But of

[1] *Brain*, vol. 102, page 153.

course to explain the discharge of sensory neurones without external stimulus, we must assume in them a tendency to discharge as soon as there is a sudden reduction in the synapses connecting them with the motor area; a kind of unstable equilibrium. Further, we need to understand wherein that degree of cortical evolution consists which makes the mental image possible. For certainly it seems that frequency and free functioning of images is peculiar to minds of the highest order of development, and is much less marked in those of even the highest vertebrates below man. May we not then suppose that the distinguishing characteristic of a cortex sufficiently highly evolved to undergo processes that are accompanied by centrally excited mental processes or images, is a high degree of instability, tension, or potential energy in its sensory centers, such that their discharge will occur 'spontaneously' whenever there is a sudden lowering of resistances at their synapses? Our seventh physiological assumption would then be: (7) In a highly evolved cortex, sensory neurones are in a state of unstable equilibrium and readiness to discharge, such that a suddenly lowered resistance at any of their synapses may induce their discharge into a motor pathway.

It is now high time to consider the arguments which favor making this formidable array of assumptions. The order in which we discuss them is not especially important; we may begin with one that is not particularly weighty, namely, that introspection seems to reveal to us a practical function for mental images, such as that we have described. For instance, take the case of a man shut up in a room from which he has previously released himself by working a combination lock. His glance falls upon the lock: the external stimulus sets up a tendency to move, which however needs the help of memory images before it can be fully executed. "There's the lock; now what were the turns I had to make?" he asks himself: the partial initiation of the response calls to its aid centrally excited processes, and the movements are successfully performed under the joint incitement of peripherally and centrally excited currents.

This, however, is an illustration rather than a real argument. The consideration which first suggested to the writer the necessity of some such physiological theory of the image as that here described was, as has been previously intimated, the fact that the association of *A* and *B* which enables *A* to call up an image of *B* does not rest merely on the simultaneous occurrence of the stimuli *A* and *B* on some previous occasion. We associate *A* and *B* only if besides being experienced together they have been attended to together. Now there are only two ways in which the necessity of simultaneous attention to *A* and *B* can be interpreted. First, the physiological changes underlying attention to *A* or *B* may be supposed to affect the sensory processes resulting from the action of the stimulus *A* or *B*. Or secondly, they may be thought of as involving characteristic motor reactions to the stimulus *A* or *B*. In a word, attention must be influential upon association either through a sensory or a motor effect. One can hardly conceive any influence of attention upon sensory processes alone which does not reduce itself to an increase of the intensity of such sensory processes. It may be said, for example, that attention, bringing about a better reception of the peripheral stimulus and a reinforcement of it by centrally excited processes, makes the sensory processes resulting from the stimuli *A* and *B* more intense, and that such intensity is necessary to bring about their association. But it would be hard to show, on such a hypothesis, why an increase of intensity that did not result from attention, but from increase in the physical force of the stimulus, should not be equally effective for the formation of associations. We know, however, that mere intensity of stimulation, apart from attention, has no significance for association. It would seem, then, as though the essential dependence of association on attention must rest on the essential motor character of association.

A second argument in favor of this theory is that it offers a convenient and clear way of conceiving the relation between imagery and learning, and of the *anschaulich* to the *unanschaulich* accompaniments of learning. It is evident that as motor processes become more completely organized, and

learning is complete, there occur *pari passu* an increase of the speed with which the movements are performed and a decrease in the amount of imagery present. It thus seems natural to connect the presence of imagery with delay and hesitation in motor response. In order, further, to understand the stages which introspection reveals in this process of the gradual disappearance of imagery, we need to note a further peculiarity which characterizes the complexer cases of learning.

This peculiarity consists in the fact that in higher learning processes we have the formation of *movement systems*. Now movement systems are characterized by the fact that when motor responses are associated, one response does not supplant another, but the performance of one response is rather an essential condition for the performance of another. The practical importance of the motor responses depends upon their all being actually made: one movement in the system is of no use without the rest. The conditions are such that there cannot be established a short-cut through the elimination of certain movements altogether: the movements derive their value each from the actual performance of the other. It is unnecessary to point out how frequently learning has to take this form. Most movements, in fact, are not simple but complex, and consist of the performance of a number of motor responses each of which would be useless without the others.

Of course such connections between motor innervations are in many cases innate. But there are others which are acquired during the lifetime of the individual. Now the most natural way in which we may suppose such movement systems to be learned or acquired is by some arrangement through which the performance of one movement may itself furnish the stimulus, or a part of the stimulus, for another movement. And the most obvious method by which the performance of one movement may regularly provide the stimulus for another is by the processes which are set up in sensory pathways by the action of the muscles themselves. Acquired systematic connections between movements are

most naturally explained by supposing the dependence of one movement in a system on the kinæsthetic or proprioceptive excitations resulting from the performance of another movement as a part of its stimulus. If reaction *BR*, to which *B* is the appropriate stimulus, is also dependent on the occurrence of the kinaesthetic excitation *KAR*, resulting from the performance of reaction *AR* to stimulus *A*, we shall have the connection of the two movements *AR* and *BR* into a system. If the connection is simply that *KAR* must combine with *B* to produce *BR*, then the system will be one of successive movements: movement *BR* must be preceded by movement *AR*. But if the connection is mutual, so that the full stimulus to movement *BR* is *KAR plus B*, and the full stimulus to movement *AR* is *KBR plus A*, then each movement demands the performance of the other, and we have a simultaneous system of movements: the connection is made in all directions. Practically all systems of movements, whether they are successive or not, involve simultaneous systems: that is, even a succession of movements is usually a succession of complex movements, or simultaneous systems of movements.

Now while as learning progresses, the tendency is for imagery to disappear and for the movements to be carried out automatically, introspection shows that at a certain stage of this process, while there is no clear visual, auditory, or verbal imagery accompanying the performance of a system of movements, there are present in consciousness certain 'imageless' or *unanschaulich* conscious processes, certain awarenesses or conscious attitudes or thoughts. These we can explain, on our theory of the basis of the image, as kinæsthetic or proprioceptive in their origin, and we can see why they should disappear only at a later stage of learning, or the formation of movement systems, than that at which visual and other *anschaulich* processes vanish. In a complex system of movements, the sensory centers connected with a given motor center are of two orders: first, those corresponding to the original stimulus to the movement, visual, auditory, or whatever it may have been; and second, the various kinæsthetic centers whose excitation results from the performance

of the other movements in the system and forms a part of the proper stimulus for the motor center we are considering. If, then, this motor center is partially excited, and there is a delay in the execution of the motor response, there are two kinds of imagery that may be aroused: the one may be visual, auditory, or in short may belong to any modality; the other must be kinæsthetic and must relate to the system of movements itself. The latter, we may suppose, constitutes the *unanschaulich* conscious accompaniments of the movement system. And since in the formation of a movement system while the actual occurrence of the original external stimuli that belonged to the various movements comes to be eliminated, the actual performance of the movements of the system never comes to be eliminated, because by definition the system cannot afford to drop out any movement, we can see that the kinæsthetic centers would be much more intimately connected with the motor center than would the sensory centers concerned with the stimuli of other modalities which originally appertained to the movements of the system. Since a slight delay in the performance of a movement calls into activity the sensory centers most immediately connected with the motor center concerned, and a longer delay induces activity in more remotely connected sensory centers, we can explain why at a later stage of learning the imagery involved should all have a kinæsthetic basis, while at an earlier stage, involving longer delays, imagery of other sorts should be called up.

It is evident, finally, that this theory with regard to the physiology of the mental image involves some addition to the current theory of attention. We have based our hypothesis about the image mainly on the undoubted fact of the dependence of recall on attention, and on the supposition of the essentially motor nature of attention. Now the ordinary account of the motor aspect of attention describes it as involving two kinds of motor processes: first, those required to hold the body quiet, so that the stimulus shall be received without distraction, and secondly, those which produce adaptation of the sense-organ for the most favorable reception of the stimulus. The motor processes of the first class have

clearly nothing in them that is specific or differentiated according to the individual character of the stimulus. The same quiet position of the body suits attention to any kind of stimulus; is adapted to listening, looking, or thinking. The adjustment of the sense organ has more relation to the peculiar nature of the particular stimulus concerned: it is of course different when the stimulus is visual and when it is auditory; for a visual stimulus it varies with the distance from which the light rays come and the point on the retina which they strike. There is even a difference in the accommodation process according to the wave-length of the light rays, since the focal distance of the lens varies with the color of the light. But for many stimuli the motor processes which relate to the adaptation of the sense organ would not be differentiated: the same adjustment process would suffice for a whole group whose associative connections would yet be very unlike. It seems to the writer of this paper that in addition to the two classes of motor effects of attention mentioned above, a third may well be added, and the statement ventured that attention to a given stimulus involves the initiation, at least, of a motor response that is peculiar to that stimulus alone. This would mean that every sensation that can be discriminated in a fusion, and every group of sensations that can be attended to as a single whole, has connected with it one or more movements which are peculiar to it alone. What, indeed, does discrimination mean if not the performance of specific motor reactions? Where would be the use of consciously distinguishing between two sensations if the two were not to lead to different movements? We need not expect always to find by introspection traces of these specific motor processes involved in attention; yet as illustrations familiar to introspection we may take the slight tendencies to articulate or to vary the tension of the vocal cords which accompany attention to sounds, or the tendencies to eye movement that accompany the visual perception of lines and forms.

This view of attention needs fuller elucidation and defense than can be given it here. Our concern at present is only to

point out the relation of the mantal image to attention, on the theory of incipient motor processes. The initiation of a specific motor response, with attention to a given stimulus, induces activity in whatever sensory centers are most directly connected with the response in question, through the previous occurrence of their own response together with it; and the activity of these sensory centers is accompanied in consciousness by images or centrally excited processes. If the question be raised as to why the motor responses whose association gives rise to images must be those motor responses concerned in attention, and not any motor responses whatever, it may be suggested in reply that motor responses which are in connection with *cortical* sensory centers (and no lower sensory centers need be supposed to possess the degree of instability required as a basis for the image) and which are subject to delay between their initiation and full execution are all of them connected with attention.

The design of this paper, expressed in a sentence, is to point out the possible significance as a factor in the physiology of the higher mental processes, of incipient activity in motor centers. While such activity is not itself accompanied by consciousness, probably, the assumption that it has an influence such as that described above affords a means of understanding how the effect of motor response upon consciousness, obviously so great and significant, may be exerted. The theory here presented renders unnecessary any such hypothesis as that of innervation sensations. The writer presents it in the hope that it may prove worthy of some discussion, and may be in some measure suggestive. In a later paper she hopes to discuss further the view of attention sketched above, and also the nature and functions of those very important movement systems, the bodily attitudes.

DISCUSSION.

THE INHIBITORY FACTOR IN VOLUNTARY MOVEMENT.

Apropos of Langfeld's recent article in this Review (November last) on voluntary movement a few remarks seem not untimely.

In the first place, as every research-report known to the present writer seems to strongly indicate, we are wasting not a little time and query over the matter of imagery in studying voluntary movement. The reason that we are still doing so probably lies in our persistent ignoring of the inevitable action of the habituation-process, for an important part of this process is the sinking into the subconsciousness of movement-sensations, visual and kinesthetic, for every movement not truly voluntary, that is, really new and difficult and, as I think, inhibitory. Langfeld himself bears witness to this in his sixth 'conclusion': "There were subjects who required imagery, visual and kinesthetic, in order to carry on the movement. There were also those who needed only the instruction verbally and at times not even that." But no one, I take it, believes that the actual neural mechanism of two persons of like age and general motor efficiency is as different as the empirical difference in imagery would imply if the latter be at all really determinant in the performance. This seems to be the general attitude of these 'conclusions' as further inspection thereof would show.

Why, then, does Langfeld say (in conclusion second) "It would be absurd to suppose that the negative [attitude], not to touch the sides, could produce the movement down the board"? In a literal sense, too literal to be more than a quibble, this may be true, but the general consent of the performer to make the experiment at all is what 'produces the movement down the board,' and, actually making it, the intention 'not to touch the sides meanwhile,' is just precisely what does, as a neural mechanism, guide the movement, since to carry out this intention as long as possible is the entire purpose or volition of service as subject. Were not this intention, be it imagery (conscious) or subconscious, the guiding part of the employed neurokinesis, somehow, of course the stylus would most always go anywhere but 'down the board.'

All this seems puerile, almost, in the saying, and it would be so

indeed were it not still the rule for psychologists to strangely enough ignore the inherent inhibitory phase of our motor ideas and with it the whole *inhibitory kinesthetic nature of the great cortex.* But when this is taken into effective account (as it surely will be universally before long) the ingenious discussion about ideomotor action will join the multitude in the limbo of outgrown ideas. For it is *not* the imagery that determines the actual behavior whether the imagery be terminal, that is visual, or kinesthetic, that is current, save *at first,* when that particular coördination of that particular action-system was early in life perhaps being acquired by the psychomotor grey of cord and cortex. One man sees the javelin's mark, the next man perceives the inherent kinesthesia—both meanwhile must keep their consciousness somewhere!, while the ingrained and long-habitual mechanism of receptors and afferent strains and adjustors and efferent strains and effectors hurls the wearied and worn javelin more or less near its goal.

None the less, it is interesting, to me at least, to observe that of Langfeld's five subjects that one ('D') who alone had consistent kinesthetic imagery made the best record, a fact Langfeld fails to note in his conclusions! although obvious in the protocols. His average for the positive instruction with the right hand was 11.2 and with the left 12.9, and for the negative instruction 10.3 with the right hand and 13.2 with the left, as compared with the other four subjects' respective 7.1, 7.0, 7.3, 8.1 and 5.4, 7.7, 11.0, 10.9, 7.2, 8.8, 8.7, 10.1 and 8.5, 8.8, 10.6, 11.8. The figures, then, suggest that, ideomotor action or none, the only subject here who had conscious kinesthetic current control was more skilled at his motor job than the others. Whether cause or effect we need not surmise (unless we presume that it was both), but no one would believe that it was 'chance.'

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